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## CHAPTER 3: LIFE HISTORY OF THE FISHES

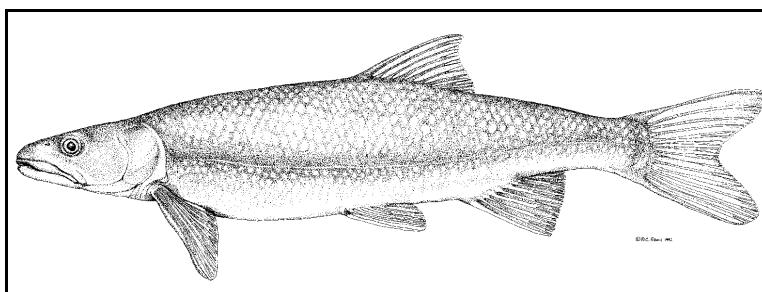
The native fish fauna of the Colorado River has one of the highest levels of endemism (fishes found only in that basin) of any basin in North America (Miller 1959). In addition, the native fish fauna includes several species highly adapted to swift-water habitats, as well as North America's largest member of the minnow family. The uniqueness of the Colorado River fish fauna includes life history strategies revolving around extensive variations in the annual hydrograph and the ability to live and prosper in a frequently flooded, highly turbid basin. Mainstem dam regulation of much of the Colorado River has changed many of the features necessary for the survival of native fishes and especially the four large mainstem endangered species (Holden 1979). Identification of the native fish community's life history needs, especially for the two endangered species, is essential for the development of flow recommendations.

Nonnative fishes, along with dams, have been implicated as a major factor in the decline of native Colorado River fishes. Minckley and Meffe (1987) suggested that many nonnative species are not as well adapted as the native species to the floods and turbidity found in the Colorado River system. This suggests that nonnative fish life history strategies may be used in the development of flow recommendations in an attempt to reduce their abundance.

This chapter describes the life history of the native and nonnative fish species that have been the focus of the SJRIP studies. The life history information presented here was developed from studies on the San Juan River, as well as through literature sources. The following section relates the biology of each species to physical processes of the river. These life history components, especially habitat needs of the native fish species, are the biological basis for much of the flow recommendations.

### COLORADO PIKEMINNOW

Colorado pikeminnow (*Ptychocheilus lucius*) is endemic to the Colorado River system and is thought to be the largest North American member of the minnow family, *Cyprinidae*, once attaining a size of nearly 6 ft in length (Minckley 1973). They were used by Native Americans for food, and early white settlers called them white salmon because of their migratory behavior. Before mainstem dams were constructed in the basin, Colorado pikeminnow were found throughout the basin, from near the brackish estuary in Mexico to tributaries in the mountains of Colorado. The advent of major



**Plate 3.1. Colorado pikeminnow (*Ptychocheilus lucius*).**

dams, beginning with Hoover Dam in 1935, reduced the ability of this species to move about the basin. The reservoirs that developed behind the dams were apparently not suitable habitat for this species, and Colorado pikeminnow never has developed reservoir populations. However, they have been occasionally found in reservoirs, such as Lake Powell, that have access to upstream riverine habitat that contains populations of Colorado pikeminnow. At present, the species does not inhabit the Colorado River Basin below Lake Powell, the upper Green River above Flaming Gorge Dam, the upper portions of the Colorado River above irrigation dams near Grand Junction, or the San Juan River above Navajo Dam. Completion of a fish ladder on the Gunnison River has resulted in Colorado pikeminnow moving upstream into the Gunnison River in 1997 and 1998 (F. Pfeifer, USFWS, personal communication), an area where they were historically found. This is the first example of a fish-passage structure specifically constructed to allow native Colorado River fishes to move upstream over a dam. The largest existing Colorado pikeminnow population occurs in the Green and Yampa river systems of Colorado and Utah, with smaller populations in the Colorado River of Colorado and Utah and the San Juan River of New Mexico, Colorado, and Utah.

Since the early 1960s, the San Juan River population of Colorado pikeminnow has been effectively isolated from other populations by Lake Powell. Although historical information about population abundance in the San Juan River is lacking, anecdotal information (summarized by Platania 1990) suggests the species was common in the system, including the lower Animas River and San Juan River now under Navajo Reservoir, prior to the completion of Navajo Dam. Based on recent SJRIP collections, the adult population of Colorado pikeminnow in the San Juan River is likely fewer than 100 individuals, and may be fewer than 50 individuals.

This section describes the life history needs of Colorado pikeminnow as they relate to potential use in flow recommendations. Much of the available information comes from research in the Green, Yampa, and Colorado rivers, and information from recent research on the San Juan River is included where appropriate. The available information shows that this species has rather specific life history needs, especially related to spawning times, spawning areas, and habitat for young fish, which are related to important changes in the basin's natural hydrograph.

## **Spawning**

Colorado pikeminnow appear to exhibit a spawning-associated homing behavior, with some members of spawning groups migrating upstream and others downstream to spawning areas. In the Green and Yampa rivers, Colorado pikeminnow may migrate more than 93 mi during spring to reach spawning areas; two major spawning areas, one in the Yampa River and one in the middle Green River, have been identified (Tyus 1985, Tyus 1990). Tyus (1985) suggested that the homing behavior of Green and Yampa river Colorado pikeminnow populations may be because of olfactory imprinting in early developmental stages (egg and early larval) before larvae become entrained and drift downstream. Tyus (1985) found that during spawning migrations, seemingly adequate habitats are passed over in favor of specific spawning sites. In contrast, radio-implanted Colorado pikeminnow in the upper Colorado River, from Palisade, Colorado, to Lake Powell, Utah, did not display discrete spawning migrations or spawning site selection; rather, these fish moved relatively short distances (< 31 mi) and spawned among many river reaches, a difference that might be

influenced by spawning habitat availability (McAda and Kaeding 1991). Alternatively, fishes in the Colorado River may have historically spawned in downstream or upstream reaches that are now disconnected by dams.

Studies on the San Juan River have shown that Colorado pikeminnow in that system appear to use at least one primary spawning area near RM 131 to 132 in an area called the Mixer (Miller 1994, 1995; Ryden and Ahlm 1996), although, based on the capture of adults (Ryden and Pfeifer 1996a) and larvae in the area (Platania 1996), another spawning site near RM 75 is possible. Migrations to the Mixer spawning area at RM 131 to 132, similar to those seen in the Green River system, have also been documented. Ryden and Ahlm (1996) documented the migration of a large female from the area of RM 74 to the Mixer spawning area in 1994, a net upstream movement of over 65 mi.

Water temperature, discharge, and photoperiod are possible spawning and/or spawning migration cues. Vanicek and Kramer (1969) suggested water temperature was the main spawning cue because spawning initiation varied up to a month from year-to-year, but gonadally mature fish were taken at water temperatures of about 21E C, approximately 1 month after water temperatures exceeded 18E C in all years of his study. Hamman (1981) was able to induce spawning at 18E C with carp pituitary injection but noted spontaneous spawning at 20 to 21E C. Haynes et al. (1984) suggested that receding flows and water temperatures of 20 to 22E C correlated with spawning. Nesler et al. (1988) developed a regression model for back-calculating ages of larval and YOY Colorado pikeminnow based on growth and fish of known ages. They used this model to predict spawning times in the Yampa River based on size of captured larvae, and indicated that flow spikes appeared to be a cue for Colorado pikeminnow spawning. During radiotelemetry studies in the Green River system, radio-implanted Colorado pikeminnow began spawning migrations as spring runoff began to recede and water temperatures increased to 14EC (Tyus 1990). Spawning migrations began from late May to early June in both the Yampa and Green rivers (1981 to 1988). Actual spawning occurred as flows receded on or near the spring solstice and approximately 38 days after peak flows. The water temperature at time of spawning was found to be over 19EC and averaged 21 to 23.4EC (Tyus 1990). However, spawning aggregations of adults occurred sooner in low water years than in high water years, suggesting that temperature may override any effect of discharge or that these cues may act in concert (Tyus 1990). Recent Colorado River studies using back-calculated spawning dates suggested that temperature is a primary factor for spawning (Trammell and Chart 1998).

Recent studies by Bestgen et al. (1998) in the Green and Yampa rivers indicated that the timing of the initiation of Colorado pikeminnow spawning was fairly constant from year-to-year, occurring from June 13 to July 1 in the Yampa River during the 7 years of their study. Temperature at the initiation of spawning was more variable, from 16 to 19E C. The spawning period lasted for about 34 days in the Yampa River. Based on larval collections from both the Yampa River and lower Green River, spawning sites and aging of larvae with otoliths, Bestgen et al. (1998) also noted that spawning initiation occurred at lower temperatures than other researchers had reported (16 to 18E C versus 18 to 20E C). This information suggests that photoperiod, or time of the year, may be more important than temperature or flow for cuing spawning.

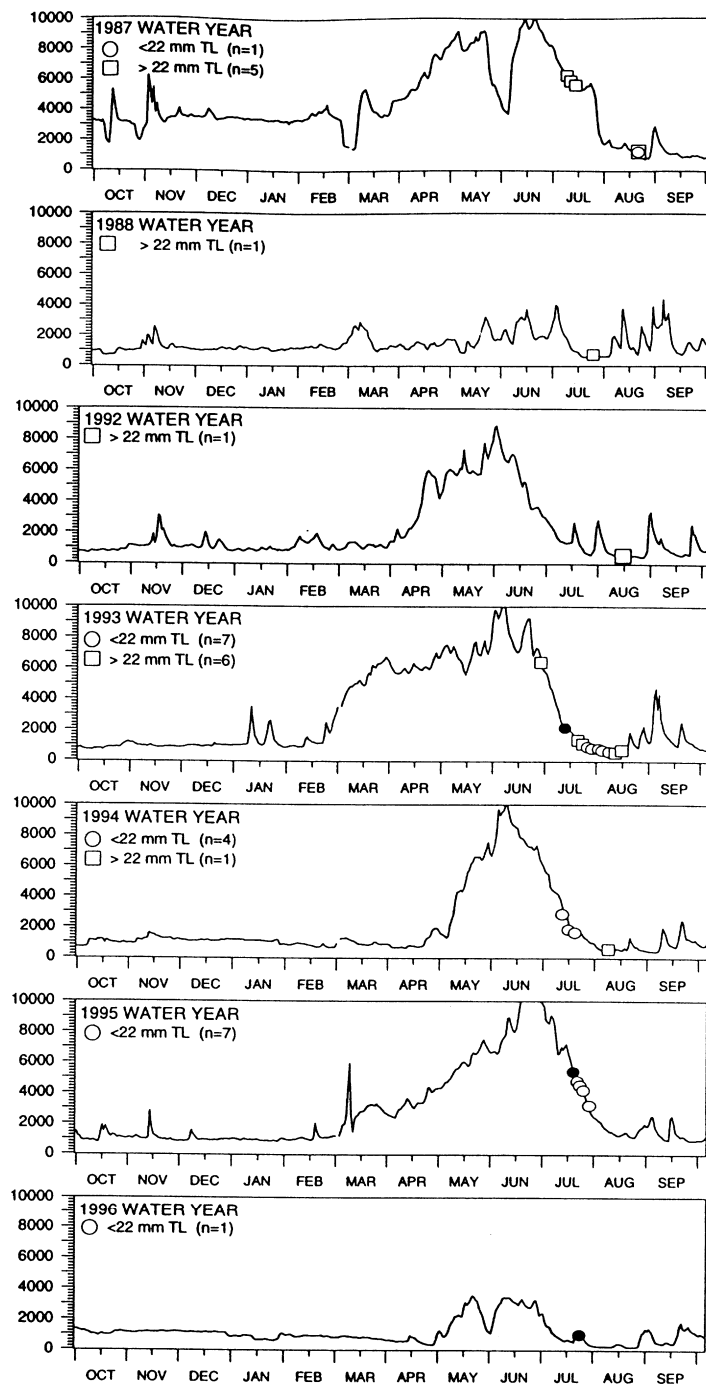
A total of 48 larvae, YOY, and age-1 Colorado pikeminnow have been collected in the San Juan River since 1987 for SJRIP and earlier studies funded by the Bureau (Holden and Masslich 1997). Back-calculated spawning dates for 34 of the larvae and small YOY, using the model from Nesler et al. (1988), showed some consistency in spawning time (Figure 3.1). Calculated spawning time generally occurred in mid- to late-July, but ranged from July 8 (1993) to August 14 (1992). Flow was considerably different between years as shown in Figure 3.1, with fairly high flows (> 2,000 cfs) occurring during predicted spawning times in 1987, 1994, and 1995, and low flows (< 2,000 cfs) during 1988, 1992, 1993, and 1996. During all years, spawning occurred near the end of the descending limb of the hydrograph. Average river temperature during the predicted spawning time was around 16E C in 1987, over 22E C in 1988, 1992, 1993, 1994, and 1996; and between 17E C and 21E C in 1995. This analysis tended to support the results of Bestgen et al. (1998) in that temperature during predicted spawning times varied. Since initiation of spawning was not verified in the San Juan River, it is not known how that factor may compare with the Yampa River site.

Miller (1994, 1995) followed radio-tagged Colorado pikeminnow adults to spawning areas in the San Juan River in 1993 and 1994. Spawning appeared to occur in mid-July during both years in the general area of RM 131 to 132, similar to the timing determined as shown in Figure 3.1. Temperatures during the spawning times were about 22E C in 1993 and 18E C in 1994, within the range seen in similar studies on the Yampa and Green rivers. Two specific sites within this area were thought to be used for spawning.

In summary, recent research has differed in what is considered the primary factor cuing Colorado pikeminnow spawning. Photoperiod, temperature, and flow likely all play a role, and each in turn may be the primary factor during different types of spring and summer flow and weather conditions.

Breeding condition of Colorado pikeminnow is discernable by nuptial tubercles on the dorsal surface of the head and back and on paired fins of males (Seethaler 1978, Tyus 1991a). Hamman (1981) reported tubercles appearing on the head, operculars, and pectoral and pelvic fins on males when temperatures reached 15E C, and tubercles over the entire surface of males (except the abdominal area and caudal fin) when temperatures reached 20E C in a hatchery raceway. At 18E C, males produced seminal plasma with active sperm. In addition to tuberculation, males also became bronze in color, whereas females remained lighter (Tyus 1990). Hamman (1981) reported that females did not demonstrate breeding condition (distended abdomen, cloaca enlarged) until shortly before spawning (water temperatures of 20E C). Females developed some nuptial tuberculation; however, this was not common. Tyus (1990) also found females to be generally larger than males.

Hamman (1981) reported that hatchery-reared males matured at 5 years of age (317 to 376 mm total length (TL)) and that hatchery-reared females matured at 6 years of age (425 to 441 mm TL). Vanicek (1967) reported sex ratios to be nearly 1:1 for 5- and 6-year-old fish after which males outnumbered females. The sex ratio reported by others suggests males greatly outnumbered females and that the ratio of males to females is closer to 4:1 (Seethaler 1978, Hawkins 1991). It is not clear whether this ratio is real or an artifact of sampling bias favoring males, since females have been



**Figure 3.1.** Back-calculated dates of *Ptychocheilus lucius* spawning based on larval and juvenile specimens collected in the San Juan River, 1987 to 1996. Hollow dots indicate *P. lucius* < 22 mm total length (TL); solid dots indicate *P. lucius* < 22 mm TL collected in drift nets; squares indicate *P. lucius* > 22 mm TL. Symbols may represent multiple individuals.

noted to grow faster, occupy deeper holes, and to be generally less active than males, especially prior to spawning (Seethaler 1978, Tyus 1990).

A spawning behavior scenario was developed based on observations of hatchery spawning (Hamman 1981); spawning habitat selection noted in field studies (Seethaler 1978, Archer and Tyus 1984, Tyus 1990); and spawning behavior of a congener (a closely related species), the northern pikeminnow (*Ptychocheilus oregonensis*) (Beamesderfer and Congleton 1981). The Colorado pikeminnow is believed to migrate to pool/riffle areas near the spawning sites. Here, they appear to use deep pools, eddies, or mixing zones to rest or stage before actually spawning. Males may gather near females in these pools until the females are ready to spawn, at which time the fish move into nearby riffles, chutes, and shallow runs with cobble substrates. After and between spawning bouts, it is believed the fish return to pools and eddies to rest. Tyus (1990) noted that radio-tagged fish aggregated in river reaches near spawning sites, staged in resting areas for hours or days, and then moved onto spawning riffles for 30 minutes to 3 hours before returning to resting areas.

Tyus (1990) described spawning areas in the Yampa and Green rivers as river reaches less than 12.4 mi long with large, deep pools and eddies, and submerged cobble, gravel, boulder, and sand bars. He noted, however, that substrates in the Yampa Canyon spawning area were predominately cobbles with some gravel and sand, whereas substrates in the Green River spawning area were mainly boulder, sand, and silt. Through radio-tracking, spawning was inferred to occur on cobble or boulder bars with the fish intermittently resting in nearby pools (Tyus 1990). Lamarra et al. (1985) more-specifically examined the substrate of “Cleopatra’s Couch,” the Yampa River spawning site. They noted that the actual spawning locations contained very clean cobble, with little or no organic material in interstitial spaces. They concluded that clean cobble was important to spawning habitat quality because the eggs were likely deposited in the spaces between cobbles.

Miller (1994, 1995) noted similar habitat use and movements with radio-tagged spawning Colorado pikeminnow in the San Juan River. Observations at the Mixer spawning area indicated that the fish used lower-velocity pools as resting areas and moved to swifter chutes and riffles for apparent spawning. Additional detail on those observations is provided in Chapter 4.

Bliesner and Lamarra (1996) compared the cobble size and amount of substrate embeddedness of the suspected Mixer spawning areas in the San Juan River (Miller 1994, 1995) with those in the Yampa and Colorado rivers. They found that although substrate size varied slightly, the general size and cleanliness of the spawning areas were similar. Colorado pikeminnow spawning areas had some of the cleanest cobble in all three rivers, as noted by the relatively large interstices between cobbles.

Relatively intensive formation and maintenance studies were conducted on the Colorado pikeminnow spawning bars in the Yampa, Green, and Colorado rivers. In all three rivers, the shape and size of the cobble spawning bars, location of sidechannels, and the distribution of coarse sediments over the bars were primarily a function of large, infrequent flood events rather than the annual spring runoff (O’Brien 1983, Harvey et al. 1993). In the Yampa River, even the supply of cobbles and boulders to the bar was dependent on large floods. Without large floods and the

upstream supply of coarse sediments, cobbles would be redistributed more uniformly throughout pools and runs. In all three rivers, large flood events reworked the bars and created sidechannels along the banks with higher elevation bars in the center of the channel. During the recessional limb of a large flood event, a center channel across the bar may evolve that can become more pronounced at low flows. These chutes across the bar are used for spawning by Colorado pikeminnow and similar bar formation has been noted at the Three Fords Rapid site on the Green River, and the Yampa River spawning site, as well as in the Colorado River at potential spawning areas (Pitlick and Van Steeter 1998).

The role of large, infrequent flood events, at or above bankfull discharge (or in the case of the Yampa River even higher, on the order of the 25-year to 100-year return period flows (O'Brien 1983, Harvey et al. 1993)), can be threefold: (1) large floods provide new coarse sediments to the river channel; (2) large floods shape, distribute, sort, imbricate and rework the cobbles bars; and (3) large floods create the sidechannels serving as Colorado pikeminnow spawning sites. Colorado pikeminnow spawning habitat viability in these three rivers is closely linked to these rare flood events because extreme flood events keep portions of the cobble bar from becoming inactive. With upstream flow regulation and nonnative vegetation encroachment, portions of the Green and Colorado rivers' cobble bars have experienced vertical accretion and bank attachment, thereby reducing the active channel width (FLO 1996, Pitlick and Van Steeter 1998).

In summary, considerable information about Colorado pikeminnow spawning behavior and site selection was gathered from the Green, Yampa, and Colorado rivers. Many similarities between these sites exist. Data from the suspected Colorado pikeminnow spawning areas in RM 131 and 132 of the San Juan River suggest that similar spawning site characteristics are also selected by Colorado pikeminnow in that spawning area.

## **Eggs**

It is assumed that eggs are deposited in cobbles and gravels within riffles and chutes during spawning events. Clean interstitial spaces in the spawning substrate likely allow eggs to fall between the substrate, preventing them from being washed downstream. Eggs are adhesive either to gravels or to other eggs in clumps (Toney 1974). Seethaler (1978) traced the developmental stages of fertilized Colorado pikeminnow eggs naturally spawned in raceways at Willow Beach National Fish Hatchery, Arizona. He noted embryo and eye formation after 1 to 2 days and hatching at 5 days in temperatures of 21.7 to 23.9E C. Toney (1974) noted that eggs were 2 mm in diameter, and newly hatched larvae were 6.5 mm in length.

Hamman (1981) noted hatching beginning 96 hours after fertilization and ending 144 hours after fertilization during a wild Colorado pikeminnow spawning event in raceways. From approximately 25,000 spawned eggs, an estimated 7,500 larvae hatched, a survival rate of 33% for a natural spawn in an artificial environment. These larvae ranged in size from 6.5 to 7 mm in length. Hatching success is likely lower in the wild.

Marsh (1985) found that Colorado pikeminnow embryo survival was significantly reduced by low (5, 10, and 15E C) and high (30E C) water temperatures, with greatest survival occurring at temperatures of 20 and 25E C, respectively. Colorado pikeminnow experienced total mortality at 15E C. Colorado pikeminnow spawn later (mid-summer) than any other native species in the Colorado River system, which may indicate why their eggs and larvae are the least resistant to cooler temperatures.

## **Larvae**

For this report, larval Colorado pikeminnow were defined as fish less than 23 mm TL. Seethaler (1978) described the development of young Colorado pikeminnow, from hatching to approximately 50 mm TL (168 days after hatching). By approximately 23 mm TL, all fins were formed, and the fish were beyond the larval stage. Seethaler (1978) broke down larval development into protolarval (feeding endogenously; less than 8 mm TL), mesolarval (feeding exogenously; 8 to 11 mm TL), and metalarval stages (fin buds forming, 11 to 23 mm TL).

Bestgen (1996) examined the effects of constant and fluctuating temperature regimes on larval Colorado pikeminnow growth, survival, and starvation resistance. Overall, growth was greatest at highest temperature (30E C) and highest food abundance. Although larvae were relatively starvation resistant (time to 50 % starvation was 17.5 to 20 days after feeding was stopped), food abundance was a greater survival factor than temperature. Temperature may be more important for providing the growth conditions that allow larvae to outgrow predation risk than for promoting direct survival. In addition, temperature preferences were higher for larvae than later young life stages, which may contribute to habitat segregation in early life stages.

Seethaler (1978) reported that at 8-mm long, larvae began to form mouths. When larvae reach 8.3 mm TL, they had resorbed the entire yolk sac. At 9.1 to 9.4 mm TL, the mouth was fully formed. Vanicek (1967) noted that cladocerans, copepods, and chironomid larvae were the main food items for Colorado pikeminnow less than 25 mm TL. Grabowski and Hiebert (1989) analyzed stomach contents of 15 Colorado pikeminnow less than 20 mm TL that were collected from backwaters in the Ouray section of the Green River in 1987 and 1988. Chironomid (predominately *Chironomus* sp.) larvae were the most abundant food item (91% frequency of occurrence). Other food items included organic material; but no phytoplankton or zooplankton were identified and no stomachs were empty.

Bestgen (1996) concluded that food abundance was more important than temperature regime (within 18 to 30E C) in optimizing growth and survival of larvae. Larvae were relatively starvation resistant, but survival and growth were greatest when food abundance was highest, regardless of temperature (from 18 to 30E C).

Haynes et al. (1984) and Nesler (1986) determined through seining and drift net surveys that larvae emerge from substrates soon after hatching and drift passively downstream with the current. Green River system Colorado pikeminnow larvae have drifted up to 100+ mi downstream from spawning areas before becoming entrained in low-velocity nursery habitats, such as backwaters (Tyus and



Haines 1991). This was not the case in the 1960s shortly after Flaming Gorge Dam was closed (1962) when Vanicek (1967) found Colorado pikeminnow larvae and juveniles in large numbers only 20 mi below the Yampa River spawning site. In the late 1960s, water temperatures from Flaming Gorge Dam became much colder at the confluence of the Green and Yampa rivers where larval pikeminnow once stopped drifting, and colder temperatures may be the reason this area is no longer used as nursery habitat. In the Colorado River above Lake Powell, McAda and Kaeding (1991) captured larval Colorado pikeminnow in nearly all river reaches sampled, suggesting that spawning was displaced throughout that section of river and that larval drift distances depend on spawning location and downstream habitat availability. Therefore, Colorado pikeminnow larvae drift from spawning areas, but the distance they drift likely depends on factors such as habitat availability and flow levels.

Bestgen et al. (1998) examined timing and success of reproduction and its relationship with hydrology and temperature. They found that high drift abundance within a year was most closely associated with increased turbidity, increasing discharge, or darkness. All of these indicated a possible antiphototactic response of increased drift (possibly a predation-avoidance response or loss of orientation) or displacement of newly hatched larvae from interstitial spaces by higher- or more-turbid flows. Differences in abundance of drifting larvae between years appeared to be related to discharge, with lower abundance of drifting larvae during very low and very high years. It is not known if low-abundance years were because of the number of spawning adults, mortality of eggs, production of young, or other factors.

During the 7-year research effort, a total of 14 larval Colorado pikeminnow were collected in the San Juan River (Platanía 1996, 1997). Eight of these larvae were collected with seines in 1994 and 1995 in Reaches 1 and 2, and another was collected with a seine in 1994 at about RM 122. The other five larvae were collected in drift nets, the standard larval fish sampling tool. Of the five larvae collected in drift nets, four were collected at RM 53 near Mexican Hat, Utah, thus suggesting that a spawning area may occur in the lower portion of the river. The other larva was collected at RM 128, 4 mi below the spawning sites at RM 131 and 132. Although numbers collected were small, this information suggests that larval Colorado pikeminnow in the San Juan River drift from the spawning areas, and may drift considerable distances to Reaches 1 and 2 to find suitable nursery habitat, similar to behavior seen in other rivers.

## **Juveniles**

Juvenile Colorado pikeminnow grow relatively rapidly during their first few years. Vanicek (1967) showed that age-0 (YOY) Colorado pikeminnow grew to about 50 mm TL, age-1 to about 100 mm TL, and age-2 to near 200 mm TL in the upper Green River. Young-of-the-year Colorado pikeminnow stocked in the San Juan River in November 1996 averaged 60 to 70 mm TL, somewhat larger than wild YOY collected in the San Juan River, which averaged about 25 mm TL in September and 35 mm in October. The stocked YOY had grown to near 200 mm by May 1998, a faster growth rate than that noted by Vanicek (1967). The faster growth rate may have been in part because of starting life in the river at a considerably larger size than wild young.

A number of authors have reported that YOY Colorado pikeminnow were found in a variety of habitat types, but were found most frequently in backwaters (Holden 1977, McAda and Tyus 1984, Tyus and Haines 1991). Holden (1977) suggested that deep compared with shallow backwaters had higher abundance of YOY pikeminnow, but Haines and Tyus (1990) did not note a difference in abundance with depth. Other habitats used include low-velocity shorelines, small low-velocity channels, and eddies. It was determined through marked and recaptured individuals that YOY fish were able to negotiate the main channel to reach lower-velocity habitats (McAda and Tyus 1984). Most discussion of habitat for the post-larval, immature life stage of Colorado pikeminnow focuses on backwaters because they appear to be important nursery habitat for this life stage until the fish are approximately 100 mm TL.

At approximately 100 mm TL, Colorado pikeminnow appear to leave backwaters and other low-velocity habitats for higher-velocity channel margin habitats. This size of young Colorado pikeminnow is not often collected, so this habitat shift is based on scattered observations by several researchers in the Green and Colorado rivers. The mechanism for this ontogenetic habitat shift is not clear, but may be related to a diet shift or predation avoidance. Trammell et al. (1993) noted a lack of stocked fingerling Colorado pikeminnow recaptures by the end of the second year. Although the authors expected high mortality, the low number of recaptures during the second year after stocking could have resulted from a habitat shift at this age and/or a size-selective bias in sampling gear. This information concurred with other studies that noted the difficulty in catching age-1+ Colorado pikeminnow, even though these fish may be recaptured later as adults (Trammell et al. 1993).

As immature Colorado pikeminnow obtain lengths of 300 to 400 mm TL, habitat again appears to change as the fish use a larger variety of habitats and appear to move more than when they were younger. Nineteen immature (<435 mm TL) age-1+ nonspawning Colorado pikeminnow that were tagged and recaptured or tracked exhibited upstream or downstream migrations, and net movement ranged from short (12 mi) to great distances (196 mi) (Tyus 1990). Large migrations of juveniles may have represented some immature spawning instinct or other life history strategy; however, it is unclear from current studies why nonspawning or immature fish migrate.

Because of the relatively low number of young Colorado pikeminnow in the San Juan River and the apparent low availability of backwater habitat, Lentsch et al. (1996) initiated a study in 1996 to investigate stocked YOY Colorado pikeminnow habitat use. In November 1996 and August 1997, 50,000 YOY Colorado pikeminnow were stocked at Shiprock, New Mexico, and 50,000 were stocked at Mexican Hat, Utah. Periodic sampling from November 1996 to April 1998 resulted in the capture of nearly 3,000 of these stocked YOY. About 60% of the recaptured YOY were collected from backwaters (the primary habitat sampled), 15% from pools, and 13% from pocket water (see Chapter 2 for an explanation of these habitat types). The other 12% of the fish were collected from a variety of other low-velocity habitats. This study tended to support the conclusion that San Juan River backwaters were a selected young Colorado pikeminnow habitat, but that a variety of other habitats were also important. It should be noted that at low-flow levels, YOY were

predominately found in secondary channels, which at that time provided the majority of low-velocity habitats in the system.

Age-1 fish from the November 1996 stocking were found during October 1997 in a variety of shoreline habitats, including shoals and eddies. While these areas typically had a higher velocity than the areas where the YOY were captured, they still would be classified as low-velocity habitats by Bliesner and Lamarra (1994, 1995). The captures of larger (age-1+) juveniles in the San Juan River supported the hypothesis discussed above that at about 100 mm TL, young Colorado pikeminnow start using higher-velocity habitats than they used during their first year of life.

Vanicek (1967) found that insects, especially chironomids, were the most important food items for Colorado pikeminnow between 25 and 100 mm TL (the approximate size range of age-0 Colorado pikeminnow). As the fish increased in size over 100 mm they became more piscivorous, primarily at sizes above 200 mm TL (Vanicek 1967, Seethaler 1978). Jacobi and Jacobi (1982) reported that fish remains comprised 85% of the stomach contents for 101 age-0 Colorado pikeminnow (22 to 59 mm TL) collected, 20% of the stomachs were empty. McAda and Tyus (1984) reported that smaller Colorado pikeminnow (22 to 40 mm TL) consumed mainly aquatic invertebrates, while larger fish (41 to 59 mm TL) consumed more fish (mainly red shiner (*Cyprinella lutrensis*)). Grabowski and Hiebert (1989) also noted that Colorado pikeminnow were highly piscivorous at about 20 to 40 mm TL. In size groups between 20 and 80 mm TL, 30 to 40% of the diet was comprised of fish remains, mostly red shiner. The most abundant item consumed was chironomid larvae, which made up most of the remaining diet (approximately 43%). Other benthic invertebrates occurred in stomachs at a lower frequency. Stomachs were only empty in June and November, which may indicate that feeding increases throughout the summer and decreases as temperatures cool into the winter. Feeding frequency is probably a function of interrelated food availability and temperatures increasing throughout the summer and decreasing with the onset of winter.

The information provided above suggests YOY Colorado pikeminnow have become more piscivorous at a smaller size since the early 1960s when Vanicek (1967) conducted his work. It should be noted that since Colorado pikeminnow spawn relatively late in the year compared with the other native fishes (see sections on other species later in this chapter), relatively few larval native fish were available in late summer before the advent of nonnative species. The fish that Vanicek (1967) analyzed were collected in 1964 through 1966, prior to the red shiner invasion of the upper Green River, which occurred after 1968 (Holden and Stalnaker 1975a). Therefore, more insects were likely found in the stomachs of YOY in the upper Green River prior to 1968 since larval fishes (native species as well as red shiner) were not available. More recent researchers have studied food habits with the availability, and generally the high abundance, of red shiner larvae in late summer, and they appear to have become a common food item of YOY Colorado pikeminnow.

## **Adults**

Adult Colorado pikeminnow in the Green River were collected from all habitat types but most frequently from low-velocity areas including runs, eddies, backwaters, and pooled canyon mouths

(Holden and Stalnaker 1975a, Tyus 1990). Size and sex may influence habitat selection; it was noted that larger female adults were captured primarily from deep holes and smaller males were captured primarily from eddies, runs, and more transitional habitats (Seethaler 1978). During spring (pre-runoff and runoff) adults tend to use backwaters, flooded mouths of washes, and other low-velocity habitats that are warmer than main channel habitats. As the water warms and flows recede, they use eddies and other low-velocity habitats associated with the main channel. During the fall and winter they continue to use lower-velocity shoreline habitats. Detailed information on San Juan River seasonal habitat use by Colorado pikeminnow adults is provided in Chapter 4. A similar annual pattern of habitat use was found in the San Juan River with extensive year-round use of eddy habitats that are typically found along shorelines.

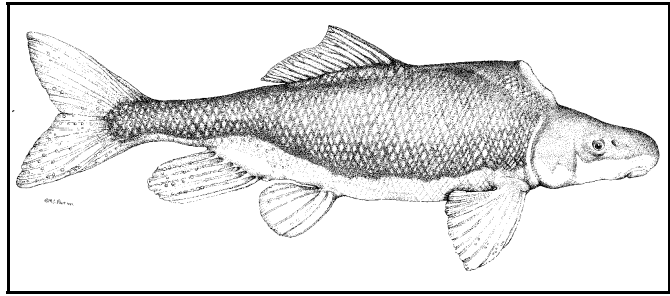
Predominately piscivorous, adult Colorado pikeminnow were the top predator in the Colorado River system before the introduction of nonnative fish species. Although little is known about Colorado pikeminnow feeding behavior, their mouth shape suggests that they are roving predators with lie-in-wait tactics (Moyle 1976, Pimental et al. 1985). Osmundson et al. (1997) noted that as Colorado pikeminnow reached maturity, they demonstrated a net movement to upstream reaches compared with immature individuals that demonstrated greater gross movement but lacked directional movement. The authors hypothesized that mature adults moved to and remained in these upper reaches because these reaches provided a greater abundance of prey, such as native flannemouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), and roundtail chub (*Gila robusta*). Upon arrival into these upstream reaches, the individuals displayed less overall movement and maintained better body condition than the individuals in the lower reaches where potential native prey was less abundant.

Miller and Rees (1997) reported that during the late summer and fall base-flow period, Colorado pikeminnow in the Yampa River exhibited two distinct activities during daytime and nighttime. Eddies and low-velocity habitats in the main channel were normally used during a more sedentary resting period during daylight hours. There was an apparent feeding behavior and active movement into shallower and faster habitats during nighttime hours. In 1996, an extremely low base-flow year, the fish remained within a habitat unit (pool or run) where they were observed during both daylight nighttime hours. In 1997, an extremely high base-flow year, the fish showed behavior similar to that in 1996 (Miller and Rees 1997). The fish were most active after sunset and exhibited what appeared to be foraging behavior. Several fish that moved to adjoining habitats spent several hours apparently foraging in riffle habitats before moving to a lower-velocity habitat. Some of the fish moved within a single habitat unit while other fish were observed to move to another habitat unit during this apparent foraging behavior. Two of the fish observed in 1997 moved through several habitat types during the 24-hour observations. On these occasions, the fish returned to their starting locations within 24 hours. These observations suggest that an entire habitat complex may be selected by Colorado pikeminnow, rather than just the resting habitat where they are most frequently collected.

## RAZORBACK SUCKER

Razorback sucker is endemic to the Colorado River Basin and once ranged from near the estuary to the upper mountainous tributaries in Colorado and New Mexico. Similar to Colorado pikeminnow, their numbers have declined as dams altered basin habitat. Unlike Colorado pikeminnow, razorback sucker remain in

some reservoirs and have survived in them for many years. However, until recently no reservoir population was shown to have natural recruitment (Holden et al. 1998).



**Plate 3.2. Razorback sucker (*Xyrauchen texanus*).**

As its name implies, the razorback sucker has a prominent keel just behind its head. It was very abundant in some parts of the basin in the 1800s (Minckley 1973), and it was reported in the San Juan and Animas rivers in the late 1800s (Jordan 1891) as far upstream as Durango, Colorado, but abundance in this system is not well understood. Several specimens were reported in a pond beside the San Juan River in 1976, and one was collected from the river near Bluff, Utah, in 1988 (Platania 1990).

The largest Upper Basin population of razorback sucker at present occurs in the Green River, with a smaller population in the Colorado River. Reservoir populations include a large Lake Mohave group and a smaller Lake Mead group, both in the Lower Colorado River Basin (Lower Basin). Recruitment is a major concern for this species, and most populations are comprised of old adults and have no, or relatively little, recruitment.

### **Spawning**

Since populations of adult razorback sucker are found in some Lower Basin reservoirs, as well as in Upper Basin riverine habitats, life history information has been gathered in both reservoir (lentic) and riverine (lotic) habitats, and both sources of information were used in this section.

Minckley (1973) stated that razorback sucker in riverine environments make annual spawning "runs" to specific river areas. The annual springtime collection of adult razorback sucker below instream diversions, in gravel pit ponds, and downstream of large reservoirs (Valdez et al. 1982, Mueller 1989, Bestgen 1990), as well as annually repeated adult razorback sucker migrations to specific areas of the Green and Yampa rivers (Tyus and Karp 1989, 1990, Modde and Irving 1998), support this statement. Razorback sucker spawning in Upper Basin riverine environments occurs later than and is not as extended as in Lake Mohave and other Lower Basin reservoirs (Bestgen 1990). In riverine habitats, ripe razorback sucker have been collected from mid-April to mid-June, but within any year, they were collected only over a 4 to 5 week period (Valdez et al. 1982; Tyus 1987; Osmundson and Kaeding 1989; Tyus and Karp 1989, 1990; Bestgen 1990). In contrast, razorback sucker spawning

in Lower Basin reservoirs extends from January to April or early May, and the spawning period does not change substantially from year-to-year.

When spring flows increased enough to allow access into bottomland areas or to create backwaters at the mouths of tributaries or dry washes, adult razorback sucker moved from colder main channel habitats into these warmer (2 to 4E C warmer) habitats, a behavior called “staging,” before spawning (Tyus and Karp 1990, USFWS 1997). However, staging may be difficult for adult razorback sucker in the San Juan River. Because of the San Juan River’s high-gradient, overbank flows that occur in some reaches tend to quickly channelize and form secondary channels, as opposed to forming flooded lowlands (R. Bliesner, Keller-Bliesner Engineering, personal communication), and mouths of tributaries that form backwaters are rare. Razorback sucker also move into backwaters and flooded tributary mouths following spawning, apparently to recover and feed (Modde and Irving 1998). Razorback sucker in riverine environments spawn at temperatures ranging between 9 and 20E C (mean = 14 to 16E C), on the ascending limb of the hydrograph (Tyus 1987, Tyus and Karp 1989, 1990, USFWS 1997). Modde and Irving (1998) tracked adult male razorback sucker with radiotelemetry and concluded that increasing flow was more important in aggregating the razorback sucker to spawn than temperature.

Razorback sucker prefer to spawn over predominantly rock or gravel substrates (Snyder and Muth 1990). Although considered broadcast spawners, razorback sucker produce discrete, identifiable redds in reservoirs (Bozek et al. 1984), which may suggest a tendency towards a brood-hiding guild. In rivers, adult razorback sucker in spawning condition have been collected in shallow, swift runs over gravel, cobble, and sand substrates at depths of 1.0 to 3.0 ft, velocities of 1.3 to 3.3 feet per second (fps) with substrate component diameters between 0.75 to 1.95 in. (McAda and Wydoski 1980). Adult razorback sucker were also observed spawning in the mouth of a side canyon wash (riverine habitat) below Hoover Dam at a depth of 3.9 to 6.5 ft, at velocities of 0.0 to 1.21 fps, and over a substrate of newly deposited gravel and cobble (Mueller 1989).

Riverine populations of razorback sucker tend to use the same spawning areas year after year, but few spawning areas have been identified in the Green and Colorado river systems. In the upper Green River, a spawning area exists at the mouth of the Yampa River, and another near Jenson, Utah (called the Escalante site) (Tyus and Karp 1990). Another spawning area is suspected to exist in the lower Green River near the town of Green River, Utah. Similar to the Colorado pikeminnow situation, no well-defined spawning areas are known in the Colorado River, but infrequent captures of razorback sucker in that area make identification of spawning areas difficult. Modde and Irving (1998) noted that some male razorback sucker in the upper Green River used more than one spawning site over a period of 3 years, including use of both the Yampa River site and the Escalante site.

Because of the low numbers of razorback sucker in the San Juan River, the SJRIP initiated experimental stocking of subadults into the river in 1994. In 1997, a more-formal plan for augmentation was developed and implemented. This provided subadult fish for research during the remainder of the 7-year research period. Between May 3 and 5, 1997, eight ripe stocked male

razorback sucker were collected from the San Juan River. Four of these ripe males were collected in a short reach of river, one fish at RM 100.5 and three fish at RM 100.2. The three individuals collected at RM 100.2 were in an area of approximately 10 square feet (ft<sup>2</sup>). Another three adult razorback sucker were observed, but they were not collected in this same aggregation. The temperature at collection locations for these eight fish ranged from 11 to 19E C. All eight adult male fish were collected over midchannel cobble riffles and run/riffles, or along the river's margins over cobble shoal/runs. Depth at these locations was 3.0 ft or less.

Male razorback sucker outnumbered females (2.5:1) at Green River spawning grounds (Tyus and Karp 1990). Total fecundity among 10 Green River razorback sucker (466 to 534 mm TL) ranged from 27,614 to 76,576 ova/female (McAda and Wydoski 1980). Recalculations performed by Minckley (1983) placed the mean relative fecundity of these 10 female razorback sucker at  $1,166 \pm 490.6$  ova/centimeter (cm) of standard length (SL) (range = 600 to 2,000). Total fecundity of an additional five ripe females (391 to 570 mm SL) examined by Minckley (1983) ranged from 74,600 to 144,000 ova/female, with the mean relative fecundity being  $1,812 \pm 90.5$  ova/cm SL (range = 1,680 to 1,908). Ovary mass of these five females averaged 10.1 % (range = 9.2 to 11.5%) of somatic body mass.

## **Eggs**

Water-hardened razorback sucker eggs, which range in diameter from 2.3 to 2.8 mm, are initially adhesive and are deposited into interstitial spaces between gravel or cobble substrates during spawning (Bestgen 1990, Snyder and Muth 1990). Egg hatching time is highly variable and dependent upon water temperature. At 10E C average hatching time was 19.4 days (Bozek et al. 1984), while at 15 to 17.2E C hatching time averaged from 5 to 11.1 days (Toney 1974, Minckley and Gustafson 1982, Bozek et al. 1984), and at 20E C hatching time averaged 6.8 days (Bozek et al. 1984). Embryo hatching success and survival is also highly variable and dependent upon water temperatures. At 10E C survival ranged from 0 to 39 % (Bozek et al. 1984, Marsh 1985), while at 14.4 to 17.2E C survival ranged 15 to 95% (Toney 1974, Bozek et al. 1984, Marsh 1985). Survival ranged from 35 to 45% at 20E C (Bozek et al. 1984, Marsh 1985) and was 29% at 25E C (Marsh 1985). No survival was reported at temperatures of 5 and 30E C (Marsh 1985).

Reasons for low survival of razorback sucker eggs include, but may not be limited to, predation and egg suffocation. Three nonnative fish species present in the San Juan River (channel catfish, common carp (*Cyprinus carpio*), and green sunfish (*Lepomis cyanellus*)) were documented as predators on the razorback sucker eggs (Minckley 1983, Brooks 1986, Marsh and Langhorst 1988, Marsh and Brooks 1989, Tyus and Saunders 1996). Suffocation may occur when adult razorback sucker spawn over sediment-laden substrates (Bestgen 1990). Also, silt deposition because of wave action and storms can bury eggs deposited into interstitial spaces during spawning (Inslee 1982, Bozek et al. 1984). Flushing and maintenance of spawning habitat during the increasing hydrograph could increase the chances of successful razorback sucker egg retention, hatching, and survival.

## **Larval and Early Juvenile Life Stage**

Larval razorback sucker hatch at 7 to 10 mm TL and begin to feed at the time of yolk sac absorption, (about 10 to 12 mm TL) (Snyder and Muth 1990). By 2 weeks of age, larval fish enter the drift, primarily at night (USFWS 1997). Recent studies in the Green River suggested that flooded bottomlands were a primary nursery habitat for larval razorback sucker and that with adequate spring flows, the larvae drift into these habitats (Modde 1996, Modde et al. 1996). In Lake Mohave, larvae spent most of the day in substrate interstitial spaces and emerged at night (probably to feed), at which time they were collected in water up to 4.9 meters (m) deep (Bozek et al. 1984). During recent Lake Mead studies, larvae were collected around floating breakwaters at depths of over 80 ft (Holden et al. 1998). In 1950 about 6,600 larval and early juvenile razorback sucker (10 to 35 mm SL) were seined from shallow margins of the Colorado River at Cottonwood Landing, Nevada, from water that was only a few inches deep but much warmer (21.1 to 24.4E C) than that in the main channel (15.5E C) (Sigler and Miller 1963).

Estimated mean daily gain in TL for otolith-aged larval Green River razorback sucker less than 35 days old (post-hatching) and reared in water temperatures of 15 to 28E C, was 0.3 mm/day (Muth et al. 1997). Diet of larval razorback sucker (11 to 18 mm TL) in Green River nursery habitats (1993 to 1996) consisted mainly of small chironomid larvae supplemented by zooplankton (mostly cladocerans and rotifers) and algae (e.g., diatoms), particularly in fish < 14 mm TL (Muth et al. 1997). Early instar Ephemeroptera are probably consumed as well, as was seen in larval bluehead sucker and flannelmouth sucker (Bestgen 1990). In lentic habitats, larval razorback sucker feed on midwater phytoplankton and zooplankton that are unavailable in turbid rivers such as the San Juan River (Marsh and Langhorst 1988, Bestgen 1990).

In recent years there has been a lack, or near lack, of recruitment in wild razorback sucker populations. Studies on Lake Mohave summarized by Minckley et al. (1991) concluded that larvae did not survive primarily because of predation by nonnative fishes. In Lake Mohave, razorback sucker as large as 30 mm TL occurred in predator-free environments, while razorback sucker exposed to predation did not exceed 10 to 12 mm TL (Brooks 1986, Marsh and Brooks 1989, Tyus and Saunders 1996). In addition, odonate nymphs also preyed upon razorback sucker larvae in Lake Mohave studies (Horn et al. 1994). Modde et al. (1996) suggested that low recruitment in the Green River was likely because of poor nursery habitat over many years (few flooded bottomlands) and high predation by nonnative fishes. Two nonnative fish species present in the San Juan River, green sunfish (*Lepomis cyanellus*) and red shiner, were offered larval razorback sucker during 4-minute trials (Tyus and Saunders 1996). Red shiner consumed 50%, while green sunfish consumed 90% of the larval razorback sucker offered. Two other experiments demonstrated that razorback sucker larvae exhibit very little defensive behavior in the presence of predators and are unlikely to survive in habitats supporting high densities of nonnative fishes (Loudermilk 1985, Johnson et al. 1993). In addition, razorback sucker are one of the first fish to spawn in the Colorado River system each spring, making their larvae available as prey early in the season when few other fish larvae are available.



Tests conducted with arsenate, selenate, selenite, and two mixtures of numerous inorganic contaminants simulating mixtures reported for sites along the San Juan River between Farmington and Shiprock, New Mexico, demonstrated that larval razorback sucker were significantly more sensitive to these contaminants than were larval Colorado pikeminnow (Hamilton and Buhl 1997). The major toxic component in the mixtures was copper. High hazard ratios obtained during this study suggested that inorganic contaminants could adversely affect larval razorback sucker in the San Juan River at sites receiving elevated inorganics from sources such as nonpoint discharges and irrigation return flows. Concentrations of these contaminants may increase or decrease in the mainstem San Juan River depending upon the source of a given contaminant.

Although fairly large numbers of larvae were found in both lentic and lotic environments, very few YOY or larger juveniles (30 to 150 mm TL) were collected in the last 40 years, as noted above. In riverine environments, eight juvenile razorback sucker (90 to 115 mm TL) were reported in backwaters near Moab, Utah, by Taba et al. (1965). Two others, each about 38 mm TL, were collected in Glen Canyon on the Colorado River before its inundation by Lake Powell, one in a backwater and one in a creek mouth (Smith 1959, Modde 1996, USFWS 1997). In 1991, two juvenile razorback sucker (36.6 and 39.3 mm TL) were collected from two separate backwaters in the lower Green River (Gutermuth et al. 1994), and two more (29 and 59 mm TL) were found in the upper Green River in 1993 (Modde 1996). The most recent collection of yearling razorback sucker occurred in 1995 and 1996 at Old Charlie Wash, a flooded bottomland along the Green River. Modde (1996) reported that 28 juveniles (74 to 125 mm TL) were recovered when the wetland was drained in 1995, and 45 juveniles (44 to 83 mm) were recovered in 1996. Minckley et al. (1991) noted that in Lower Basin reservoirs, only four small juveniles were reported (those from Lake Mohave in 1987) even though thousands of larvae were collected annually.

Based primarily on the size information gathered by Modde (1996) and on growth rates from reared wild-caught larvae in Lower Basin ponds (Burke 1995), young razorback sucker grew from 50 to 150 mm their first year, and were 200 to 300 mm TL or more by age-1. Young razorback sucker in warm, food-rich habitats appeared to grow faster than those in cooler habitats, but individuals within the same cohort of larvae reared in the same aquaria showed considerable growth variation during the first year. The information gathered in both the Upper and Lower basins in recent years suggest that predation by nonnative species is a major contributor to young razorback sucker mortality, but habitats that have extensive cover and high levels of food (i.e., flooded bottomlands in the Green River) allow some young to escape predation.

### **Late Juvenile Life Stage**

Similar to yearlings, very few larger juvenile razorback sucker (150 to 400 mm TL) were collected in recent years, so little is known about the life history of this size fish. As noted above, late juvenile razorback sucker were not collected from Lake Mohave, but from 1973 to 1986, a number were found associated with irrigation canals along the lower Colorado River (Minckley et al. 1991). During recent studies on Lake Mead, five subadults were collected (318 to 381 mm TL), one in 1994, two in 1997, and two in 1998 (Holden et al. 1998). None of these Lower Basin captures provided information on life history except for the fact that in some habitats (Lake Mead and the

lower Colorado River canals), young razorback sucker escaped predation and may have recruited to the adult population. These captures suggest that perhaps improved habitat conditions, such as more abundant food and extensive cover, may help young razorback sucker escape predation.

Two experimentally stocked juvenile razorback sucker were recaptured in the San Juan River from which information on habitat use was determined. The first (231 mm TL), recaptured on March 9, 1995, was seined from a pool at the downstream end of a midchannel cobble island complex at RM 94.2, near Montezuma Creek, Utah. The pool was 1.4-ft deep, 4-ft wide, and 15-ft long, had a slight flow-through on the upstream end, and was 3 degrees warmer (9E C vs. 6E C) than the main channel. The second razorback sucker (216 mm TL), recaptured October 21, 1997, was seined from a large backwater at RM 77.3 by the UDWR. The backwater was several feet deep, had a silty substrate, and was 1E C warmer than the main channel (E. Archer, Department of Fisheries and Wildlife, Utah State University, personal communication). Additional information on habitat use was collected from radio-tagged razorback sucker in the San Juan River, and that information is discussed in detail in Chapter 4.

The diet of juvenile razorback sucker is also not well known. Stomach contents collected from eight young juveniles 90 to 115 mm long contained “algae and bottom ooze” (Tabata et al. 1965). It is likely that the “bottom ooze” was ingested while feeding upon benthic invertebrates or algae.

## **Adult Life Stage**

Adult razorback sucker have been aged at up to 44-years old (McCarthy and Minckley 1987). Studies by Hamman (1985) on hatchery-reared razorback sucker have shown that males can reach adulthood at age-2, or less than 350 mm TL, while females can reach adulthood at age-3, or greater than 390 mm TL. The juvenile razorback sucker collected recently in Lake Mead (318 to 384 mm TL) did not show signs (e.g., tuberculation, ripeness) of sexual maturity, while mature adults captured at the same time had obvious secondary sexual traits (Holden et al. 1998). This suggested that wild fish may not mature as quickly as hatchery- or pond-reared fish. In the Upper Basin, adult razorback sucker occupy habitats during the course of a year ranging in temperature from near 0E C (ice-covered) to 25E C (Bestgen 1990). In the Lower Basin, occupied habitats were somewhat warmer, ranging from 10 to 32E C (Dill 1944). Optimal summer temperatures for adult razorback sucker were 22 to 25E C (Bulkley and Pimentel 1983).

Most of the pertinent information that applies to adult razorback sucker year-round habitat use in the San Juan River and habitat use in other Upper Basin rivers during spawning seasons is presented in Chapter 4 of this report. Bestgen (1990) stated that razorback sucker were known to use backwaters, sloughs, and oxbow lakes. None of these habitat types were particularly prevalent in the San Juan River. Winter habitat observations in the Green River documented that adult razorback sucker were fairly sedentary and exhibited no distinct diel movement patterns (Bestgen 1990). Winter radiotelemetry in the San Juan River seemed to indicate that there was a threshold temperature somewhere between 0 and 3E C that determined razorback sucker activity during daylight hours. At warmer temperatures, razorback sucker moved into main channel run habitats,

presumably to feed, for short periods of time during the day before returning to slow or slackwater habitats along the river's margins (Ryden and Pfeifer 1996b).

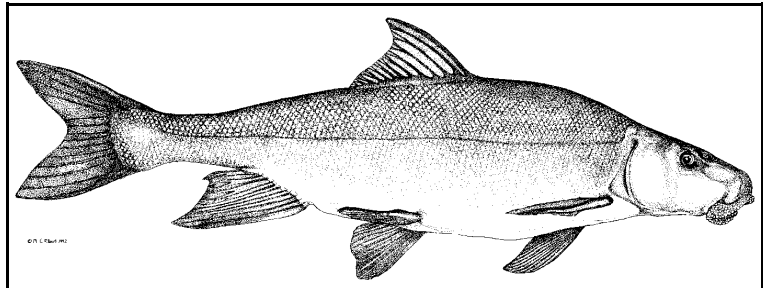
Sigler and Miller (1963) stated that the diet of adult razorback sucker consisted of “algae and midge larvae.” Other studies identified immature Ephemeroptera, Trichoptera, and Chironomidae as well as algae, detritus, and inorganic material from adult razorback sucker digestive tracts (summarized in Bestgen 1990).

## OTHER NATIVE FISHES

This section discusses the other common native fish species found in the study area. Not included here is the cool-water species, mottled sculpin (*Cottus bairdi*), which is found primarily in the upper portion of the study area. These accounts are briefer than those presented for the two endangered species, partially because less is known about these species and also because the flow recommendation emphasis is on the two endangered species.

### **Flannemouth Sucker**

Endemic to the Colorado River Basin, the flannemouth sucker has been extirpated from most of its former range in the Lower Basin, especially the area below Hoover Dam (McAda 1977). It is the most abundant native species in the San Juan River (Ryden and Pfeifer 1996a) as well as all Other Upper Basin rivers (Holden and Stalnaker 1975).



**Plate 3.3. Flannemouth sucker (*Catostomus latipinnis*).**

Flannemouth sucker spawn in spring and early summer, typically during May and June, and on the ascending limb or peak of the hydrograph—although timing can vary spatially within and between river systems as hydrologic and temperature regimes vary (Valdez 1990). They are broadcast spawners, and there is no parental guarding of eggs. Eggs are demersal and initially adhesive (Muth and Nesler 1993). Ripe females were not captured past early June. Although spawning was not actually observed, “ripe male and female flannemouth sucker were captured over the same gravel bars used by razorback suckers. . . .” The fish were collected in water about 3.0 ft deep and moving about 3.25 fps. Substrate ranged in size from 0.75 to 1.95 in. in diameter. Assuming spawning occurred at this exact location, such habitat approximately corresponds to riffle-run or run habitat in the San Juan River (Bliesner and Lamarra 1996). In the White River, during May and early June, Lanigan and Berry (1981) found large, ripe flannemouth sucker in water less than 3 ft deep, near sand bars. No indication of spawning habitat was provided. Muth and Nesler (1993) similarly reported flannemouth sucker spawning in gravel/cobble bars or riffles, with depths generally <3.75

ft. Spawning was not directly observed in the San Juan River; however, the larval drift period for this species was completely bracketed in 1994 from June 20 to July 1 (Archer et al. 1995).

Flannemouth sucker larvae in the Colorado River were found in the midchannel as passive drift and along quiet shoreline areas (Carter et al. 1986). From June to July in the San Juan River, this species was common in the drift from Four Corners to Mexican Hat, Utah, but was typically more common at the former site (Platania 1996). Larvae were likely also present in backwaters and other low-velocity habitats along the shoreline; however, the study design from 1991 to 1997 did not sample low-velocity habitats in June and July. In the San Juan River, larval drift of flannemouth sucker was observed during August and appeared to be related to displacement by storm events (Platania 1996).

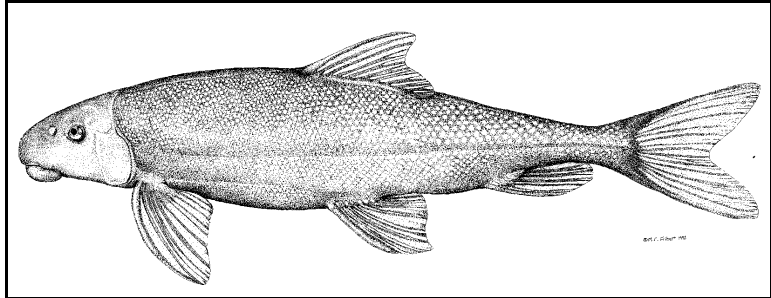
Age-0 flannemouth sucker, like the early life stage of many fish species, were commonly found in low-velocity habitats such as backwaters, shorelines, and pools in the Colorado River (Valdez 1990). In the San Juan River, they were most abundant in backwaters and flow-through backwaters in the upper portion of the river between Hogback Diversion and the Four Corners area in the spring (Buntjer et al. 1993). The abundance of age-0 and age-1 fishes tended to decline from spring to fall (Buntjer et al. 1993, 1994; Archer et al. 1995, 1996; Propst and Hobbes 1996), following spawning. This was likely because of mortality and a shift in habitat use from low-velocity habitats to other less-efficiently sampled habitats with faster current. By early spring, these young flannemouth sucker still occupied habitats such as backwaters and pools but in relatively low numbers (Buntjer et al. 1994).

In the San Juan River, the abundance of juvenile flannemouth sucker tended to increase in the lower reaches downstream of Aneth, Utah (Ryden and Pfeifer 1996a). Juvenile distribution was fairly well correlated with shoreline slackwater habitats in the spring, particularly in the lower canyon reaches, and moderately correlated with cobble-type habitats in the fall when overlaid with aquatic habitat distribution. It is not known whether this observation is an artifact of sampling efficiency, actual habitat use, or both, but flannemouth sucker occurrence appeared to be correlated with these habitats.

McAda (1977) reported that adult flannemouth sucker were collected in all habitat types in the Upper Basin, including riffles, runs, and pools, but were most abundant in pools. In the San Juan River, they were captured in a wide variety of habitats, including riffles, runs, pools, and eddies; however, no telemetry data exist to document actual habitat use. During post-runoff base-flow conditions, the distribution of juvenile and adult flannemouth sucker was only moderately correlated to cobble-type habitats (e.g., riffles and riffle/runs), probably because of their extensive use of other habitat types such as runs and pools. Winter habitat use by flannemouth sucker has not been well studied, although habitat use is likely varied, similar to other times of the year (Holden and Stalnaker 1975a).

## **Bluehead Sucker**

Bluehead sucker is native, but not endemic, to the Colorado River Basin, and is also found in parts of the Walker River in Nevada (Valdez 1990), the Bear and Weber river drainages in Utah and Wyoming, and the upper Snake River Drainage in Idaho and Wyoming (McAda 1977).



**Plate 3.4. Bluehead sucker (*Catostomus discobolus*).**

Bluehead sucker inhabit the relatively cooler, clearer waters of the upper and middle portions of rivers and streams, preferring faster flowing water over rocky substrate (Holden and Stalnaker 1975a, McAda 1977, Woodling 1985). The high use of these habitats is probably largely related to feeding. These fish possess a rigid upper lip with a cartilaginous ridge, designed for scraping cobble for diatoms and other potential food sources (Woodling 1985).

Bluehead sucker in the Green River usually spawn in mid-June to mid-July, typically during the descending limb of the runoff period, at temperatures above 15°C (Holden 1973, McAda 1977). Like flannelmouth sucker, these fish are broadcast spawners with demersal, initially adhesive eggs (Muth and Nesler 1993). Spawning was observed over a gravel bar during early May in a small Arizona tributary, Kanab Creek, by Maddux and Kepner (1988). Females were typically accompanied by no more than two males during the spawning act, which occurred in water ranging from 3.5 to 11.3 in. deep (0.624 in.) with a constant velocity of about 1.15 fps. Substrate consisted primarily of loose gravel (0.257 ± 2.48 in. diameter). Studies on the San Juan River indicated that such habitat resembles what was classified as a cobble shoal, where mean column velocities ranged from 0.66 to 1.31 fps and depths ranged from 3.9 to 5.85 in. (Bliesner and Lamarra 1996). No direct observations of bluehead sucker spawning were made in the San Juan River; however, the overwhelming relative abundance of YOY within the reach of the Mixer (a reach of relatively complex and dynamic habitats located 10 mi or so upstream of the Four Corners Bridge) to Hogback Diversion (Archer et al. 1996), indicated that the bulk of spawning activity occurred in this reach or further upstream. The majority of adults were found from the Mixer upstream to Farmington, New Mexico (Ryden and Pfeifer 1996a).

Bluehead sucker larvae were common in the midchannel as passive drift and along shoreline areas with slow current shortly following the spawning period (Carter et al. 1986, Valdez 1990). In the San Juan River, the period of peak drift for this species (late July) tended to be several weeks later than for flannelmouth sucker, because of their later spawning period. This species tended to occur much less frequently in the drift of the lower (Mexican Hat, Utah) than the upper (the Mixer) sampling sites in the San Juan River (Platania 1996), which may indicate a limited downstream drift. However, considering that the majority of adults resided in the upper reaches of the river, larvae could have still drifted extensively and data collected in other systems would indicate that they do drift (R. Muth, USFWS, personal communication; T. Chart, UDWR, personal communication). Bluehead sucker larvae were also captured along the shorelines about 2 mi downstream of Clay Hills

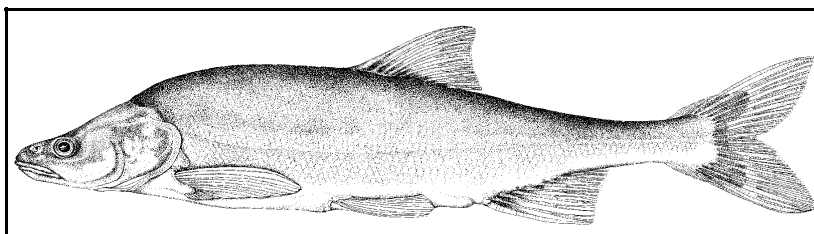
Crossing (RM 0) in the San Juan River during August 1995 but were infrequent (0.4% of total) in the catch (Schaugaard et al. 1996).

Age-0 to age-1 bluehead sucker inhabited quiescent habitats along river margins such as backwaters and eddies (Valdez 1990). They were regularly collected in backwaters and flow-through backwaters in the San Juan River during the runoff months of June and July (Buntjer et al. 1993, 1994) and in a variety of habitats such as backwaters, flow-throughs, and secondary channels from summer to fall. However, their abundance declined sharply during the course of a summer (Buntjer et al. 1993, 1994; Archer et al. 1995, 1996; Propst and Hobbes 1996). Like flannelmouth sucker, little published information exists for winter habitat use by these younger fish. Backwaters, flow-throughs, pools, and other low-velocity habitats were still occupied during early spring (March/April), but at very low densities (Buntjer et al. 1994). These fish used swifter habitats (e.g., riffles and runs), in greater numbers as they increased in size.

Juvenile and adult bluehead sucker tended to be most common in the upper reaches of Upper Basin tributaries and typically occurred in habitats with rocky substrate, usually riffles, at all times of the year (Holden and Stalnaker 1975a, McAda 1977, Valdez 1990). Ryden and Pfeifer (1996a) conducted electrofishing surveys on the San Juan River between Farmington, New Mexico, and Clay Hills Crossing, Utah, and indicated that bluehead sucker tended to be most abundant in the area upstream of the Mixer. The distribution of juveniles and adults was virtually identical to that of adults during base flow and highly correlated with cobble-type habitats, particularly riffles in the upper half of their distribution. This was likely related to feeding, although improved capture efficiency in shallower, cobble-bottomed habitats may also be a factor. The distribution of these fish remained largely unchanged during higher spring flows. It appeared likely that they occupied similar cobble habitats during spring although higher velocities and greater depths may have been more common.

### **Roundtail Chub**

Found throughout the Colorado River Basin, the roundtail chub historically was common in most tributaries of the Upper Basin (Vanicek 1967, Holden and Stalnaker 1975a and b, Joseph et al. 1977). Holden



**Plate 3.5. Roundtail chub (*Gila robusta*).**

and Stalnaker (1975b) reported that roundtail chub was abundant or common at all sites sampled in the Yampa River and at most sites in the Dolores River. McNatt and Skates (1985) found roundtail chub common at most sites in the Green River and Yampa River at Dinosaur National Monument, and Olson (1967) stated that during 1965, roundtail chub was common in Navajo Reservoir collections on the San Juan River. Recent collections on the San Juan River found relatively few roundtail chub, but larger populations were found in several tributaries (Miller et al. 1993, Miller 1995). Therefore, it appears that a roundtail chub population does not currently exist in the San Juan River mainstem and that the few individuals collected likely came from tributaries.

Little information is available describing the details surrounding the specific spawning activities of roundtail chub. Because of the high turbidity commonly associated with the Colorado River and its tributaries, the exact spawning procedure and habitat used by roundtail chub have not been observed. Most roundtail chub that were ripe when collected were found occupying shoreline eddies when captured (Vanicek and Kramer 1969, Karp and Tyus 1990). Vanicek and Kramer (1969) reported that exact spawning sites or deposited eggs were never observed; however, all ripe fish were collected in eddies or shallow pools with boulder or cobble substrate. Although no observations indicated that eddy habitat was used for spawning, Karp and Tyus (1990) stressed the importance of this habitat during spawning whether it was used as a spawning, feeding, or staging area.

Roundtail chub in the Upper Basin began spawning when water temperatures reached about 18.3°C (Vanicek and Kramer 1969, Joseph et al. 1977). In most Colorado River tributaries, this temperature increase coincided with a decrease in discharge after peak runoff. Karp and Tyus (1990) indicated that spawning of roundtail chub in the Yampa River at Dinosaur National Monument occurred between mid-May and early July. Minckley (1973) suggested that an average-sized female roundtail chub would produce about 2,000 eggs. Muth et al. (1985) stated that roundtail chub females produced about 39,500 to 41,350 eggs per kilogram (kg) of body weight. The eggs hatched 7 to 15 days after spawning, depending on water temperature. Young roundtail chub began feeding about 10 days after they hatched (Minckley 1973). During the first 54 days after hatching, the mean daily growth rate was 3 mm for cultured fish (Muth et al. 1985). Carter et al. (1986) suggested that roundtail chub actively drifted during the mesolarval stage of development. Drifting activity occurred primarily after mid-July and appeared to increase with warmer water temperatures.

Feeding habits of roundtail chub were described as “opportunistic” and “sporadic” (Vanicek 1967). Joseph et al. (1977) reported that roundtail chub of all age classes were primarily carnivorous. Young roundtail chub typically inhabited the slower, shallower water along the shore of the stream (Sigler and Miller 1963). Young roundtail chub in the Green River consumed primarily aquatic insects (particularly Chironomidae larvae and Ephemeroptera nymphs) (Vanicek 1967, Vanicek and Kramer 1969). Joseph et al. (1977) provided additional evidence of young roundtail chub feeding mostly on aquatic invertebrates found at the bottom of pools and eddies. Most growth in young fish occurred between late May and October (Vanicek 1967).

Roundtail chub over 200 mm TL consumed a greater variety of prey items than smaller individuals. Adult roundtail chub were reported to feed on filamentous algae, aquatic invertebrates, terrestrial invertebrates (especially grasshoppers and ants), fishes, and plant debris (Vanicek and Kramer 1969, Joseph et al. 1977). Minckley (1973) indicated that adult roundtail chub may have also consumed their own eggs as well as the eggs of other fish species. Olson (1967) reported that the diet of roundtail chub was similar to that of Navajo Reservoir rainbow trout. The diet of both species in the reservoir was primarily plankton with some aquatic insects.

In large rivers, adult roundtail chub may reach 400 to 450 mm TL; however, adult size in the smaller tributaries can be less than 200 mm (Joseph et al. 1977). Karp and Tyus (1990) collected ripe males that ranged from 292 to 419 mm TL, and ripe females from 343 to 380 mm TL. Vanicek (1967)

reported that most roundtail chub became sexually mature by age six; however, Muth et al.(1985) reported that spawning females were collected ranging in age from 5 to 7, and spawning males ranged from age-5 to age-8. Prior to spawning, male and female roundtail chub typically developed breeding tubercles. These tubercles were usually uniformly scattered over the surface of the male; however, they were mostly restricted to the head and caudal peduncle of the female. Both sexes developed an orange-red coloration on the ventral surface and ventral fins (Muth et al.1985) which was more pronounced on males.

At present, there is concern regarding the status of roundtail chub in the Colorado River Drainage. Historically, the roundtail chub may have been the most abundant carnivore in the Upper Basin (Holden and Stalnaker 1975a). Recently, a decrease in range and abundance was documented at several locations (Vanicek et al. 1970, Minckley 1973, Joseph et al. 1977, Kaeding et al. 1990). Joseph et al. (1977) suggested that declines in roundtail chub populations were often correlated to the introduction and establishment of predatory nonnative fishes. It is likely that roundtail chub is preyed upon by native and nonnative predators sharing their habitat. Reduction of roundtail chub populations was documented in the San Juan River downstream from Navajo Dam (Joseph et al. 1977), and in the Green River downstream from Flaming Gorge Dam (Vanicek and Kramer 1969, Karp and Tyus 1990). Low numbers of roundtail chub in the San Juan River may be attributed to the change in water temperature induced by Navajo Dam; however, rotenone was used to eliminate nongame species from approximately 70 mi of the river during 1961, which may have made a large, long-lasting impact on the local population (Olson 1962). Roundtail chub was also eliminated from the reservoir portions of the rivers, including the area of Navajo Reservoir and Flaming Gorge Reservoir.

Vanicek and Kramer (1969) provided evidence suggesting that roundtail chub growth rate decreased in the Green River downstream of Flaming Gorge Dam because of a decrease in summer stream temperature. Absence of certain year-classes suggested that successful spawning did not occur during some years in the Green River between Flaming Gorge Dam and its confluence with the Yampa River (Vanicek and Kramer 1969). Vanicek et al. (1970) found that almost no roundtail chub occurred in the Green River within about 20 mi of the Flaming Gorge Dam. Following inlet modification of Flaming Gorge Dam to provide warmer release flows, roundtail chub again started spawning successfully in the Green River above the mouth of the Yampa River (Holden and Crist 1981). Karp and Tyus (1990) indicated that the change in temperature and flow regime caused by Flaming Gorge Dam may have been responsible for a decline in roundtail chub populations in the Green River upstream from its confluence with the Yampa River, but they also suggested that a negative interaction between roundtail chub and channel catfish occurred and resulted in a competition for food and predation by channel catfish on roundtail chub.

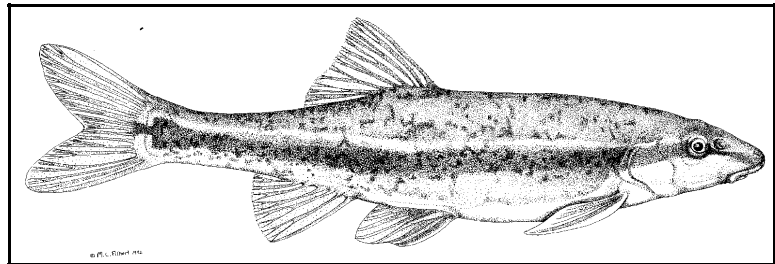
There is some speculation that human-induced changes to the Colorado River Drainage may have contributed to the breakdown of reproductive isolation mechanisms that have evolved between roundtail chub and other chub species (Kaeding et al. 1990). Karp and Tyus (1990) collected one specimen that was considered to be a roundtail x humpback hybrid. Morphology of many individuals ranges from more humpback-like to more roundtail-like with a full range between (T.



Chart, UDWR, personal communication). Kaeding et al. (1990) reported that hybridization is possible between roundtail chub and humpback chub, and also between roundtail chub and bonytail chub. Spawning of roundtail chub and bonytail chub is concurrent in time but thought to be spatially separated (Vanicek 1967). Kaeding et al. (1990) additionally suggested that the difference between roundtail chub and humpback chub microhabitat selection for spawning was an important mechanism contributing to the reproductive isolation of each species. Because so little is known about specific spawning requirements of roundtail chub and other chubs in the Colorado River Drainage, further research must be conducted to develop or confirm theories regarding the spawning success and recruitment of roundtail chub.

### **Speckled Dace**

Speckled dace, *Rhinichthys osculus*, is perhaps the most ubiquitous and, in many lotic systems, the most common native fish species west of the Rocky Mountains (Minckley 1973, Wallace 1980, Tyus et al. 1982).



**Plate 3.6. Speckled dace (*Rhinichthys osculus*).**

Its range extends from southeast

Arizona (Minckley 1973) and southwest New Mexico (Sublette et al. 1990) north through the Great Basin (Sigler and Sigler 1987) and Pacific coastal states (Moyle 1976) to south-central British Columbia (Scott and Crossman 1973). Across its range, it occupies a variety of streams ranging from small desert streams (Barber and Minckley 1966) to large rivers such as the Colorado (Tyus et al. 1982) and Columbia (Wydoski and Whitney 1979).

In the San Juan River Basin of New Mexico, Colorado, and Utah, speckled dace was widespread and comparatively common (Miller 1994, Ryden and Pfeifer 1996a, Propst and Hobbes 1996). In San Juan River secondary channels, speckled dace was the most common native fish species in summer and autumn fish collections (Propst and Hobbes 1996). Although it was found in a variety of habitats, it was most common in riffles and runs with moderate to rapid velocity water over gravel and cobble substrates (Gido et al. 1997; Gido and Propst, in press).

Speckled dace is a stout, round minnow that is flattened slightly ventrally. It possesses a triangular shaped head with small eyes, subterminal mouth, and pointed snout. Head length is roughly equal to body depth. Coloration is typified by an olivaceous or gray back and sides with scattered spots above the midline. The species usually possesses a dark lateral band extending from the tip of the snout through the caudal peduncle. Adults are 45 to 100 mm TL (Wallace 1980, Sigler and Sigler 1987). Minckley (1973) described breeding males "... with brilliant red on bases of paired fins and on body above those fins, on and near anal fin base, the lower caudal lobe, the mouth, and near the upper part of gill cleft."

Deacon et al. (1987) noted that speckled dace preferred water temperatures around 15.8E C and had a low tolerance of water temperatures higher than 30E C. Lowe et al. (1967) suggested that low

tolerance of reduced oxygen, along with high temperatures, were the reasons why speckled dace was only found between elevations of 5,905 and 6,890 ft in Arizona.

John (1963) described the reproductive cycle of speckled dace as bimodal, with discrete peaks of spawning in early spring and late summer. Spring spawning was associated with increased water temperatures, day length, and spring runoff. Spawning in late summer was associated with higher flows during or following rain events. A single flood was not adequate to stimulate spawning in early summer, but would in late summer. John (1963) therefore hypothesized that photoperiod is the determining factor in regulating the reproductive period of speckled dace. Nests or spawning sites were typically located in areas with gravel substrate, slow or no velocity, and little if any vegetation (John 1963). Several males, up to 60 in one site, would occupy a nest, persistently working over the gravel with their mouths. This activity, and the constant turbulence associated with so many males swimming in one area, produced an area clean of silt, plant material, and debris. Females would only enter the area periodically prior to actual spawning to “test” the spawning substrate. Males would converge on the female and “a vibrating swarm” would accompany the female’s vigorous tail lashing (John 1963). Once spawning was initiated, a female would enter the nest site repeatedly, depositing a few eggs at a time (John 1963). The “swarm” of males would again converge on the female and apparently release sperm simultaneously. After the female left the nest site, eggs that did not immediately fall below the first layer of gravel were immediately preyed upon by the males. Spawning activity would continue in one area for up to 5 days, during which several females would use the nesting site. Eggs were located on the under surfaces of stones or in the interstitial spaces of the finer gravel below (John 1963). In the laboratory, hatching occurred within 6 days at 18 to 19E C. Larval fish remained hidden in the interstices of the gravel for up to 8 days or when the free-swimming stage was reached (John 1963). Winn and Miller (1954) and Snyder (1981) described the larval stages of speckled dace.

John (1963) concluded that female speckled dace typically matured in their second year (age-1), but that smaller age-1 fish were immature. Further studies by John (1964) revealed that speckled dace live 3 or 4 years at most. Females are typically larger and mature later than males.

The diet of speckled dace was comprised almost entirely of aquatic insects (Greger and Deacon 1988, Angradi et al. 1991); however, detritus and plant material were also collected from digestive tracts of speckled dace (Schreiber and Minckley 1981, Williams and Williams 1982). Feeding was most active at night (Van Eimeren 1988).

Speckled dace are an important component of the native fish community in the San Juan River. Commonly collected in both primary and secondary channels (Propst and Hobbes 1996, Ryden and Pfeifer 1996a), speckled dace were probably an important food item for Colorado pikeminnow and roundtail chub.

## NONNATIVE SPECIES

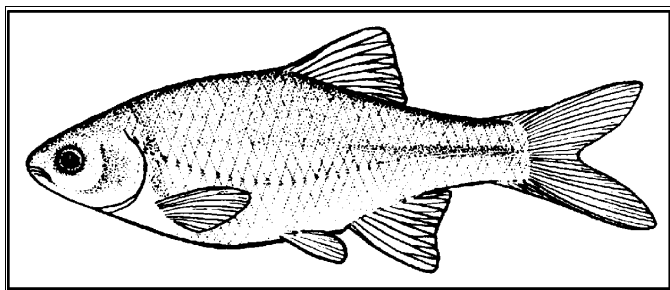
The decline of western native fish species was identified by Minckley and Deacon (1968) as, in large part, because of the introduction and establishment of nonnative species in association with habitat alteration. Channel catfish and common carp, two of the most abundant large-bodied nonnative fishes, were introduced in much of the Colorado River Basin during the late 1800s or early 1900s. Other abundant forage species, such as red shiner and fathead minnow (*Pimephales promelas*), were introduced later, after sport fisheries were established in reservoirs that were constructed in the mid-1900s. However, the successes observed in the introduction and establishment of a variety of nonnative species were realized at the expense of native species. Habitat alterations within the Colorado Basin, because of the construction and operation of dams, allowed for the wide dispersal of nonnative species in concert with the decline of natives. Interaction between native and nonnative fishes has been recognized as an obstacle to the conservation of native species and has been the focus of a variety of management efforts (Nesler 1995, Lentsch et al. 1996) in the Colorado River Basin. Mechanical removal of nonnative fishes is a standard practice in SJRIP sampling. Minckley and Meffe (1987) provided evidence for the importance of unregulated rivers in the maintenance of native fish communities, even in the presence of nonnative forms. As noted above, populations of native fishes, especially the endangered forms, were still strongest in the Green River—the system that was the least altered hydrologically. The mechanisms for species replacement vary, but predation by nonnative species was documented as a major factor in the decline, as well as a major deterrent to the reestablishment of native Colorado River fishes (Marsh and Langhorst 1988, Marsh and Brooks 1989).

Understanding the biology and habitat requirements of nonnative species and the associated impacts on native species in San Juan River studies was necessary to determine if flow recommendations could be used as a management tool to decrease nonnative species numbers. This section discusses the life history of the four abundant nonnative fish species in the San Juan River; red shiner, fathead minnow, channel catfish, and common carp. Specific information from SJRIP studies related to distribution, abundance, habitat use, and related factors of these species in the San Juan River are provided. Life history details have generally been developed through literature review.

### **Red Shiner**

Red shiner is native to streams of the south-central Mississippi and western Gulf Coast drainages in the United States and northeastern Mexico (Matthews 1980). In New Mexico, the native range of red shiner encompasses the Rio Grande, Pecos, and Canadian drainages (Sublette et al. 1990). In Colorado, it is native to all drainages east of the Continental Divide (Wordling 1985).

Red shiner was first documented in the Colorado River system in the 1940s in the Lower Basin



**Plate 3.7. Red shiner (*Cyprinella lutrensis*).**

reaches below Lake Mohave (Hubbs 1954). Since then, this nonnative cyprinid has become widely distributed throughout the American Southwest. The species was probably introduced to the San Juan River system during the 1950s or 1960s (Sublette et al. 1990), and it is now common in the river between the Hogback Diversion in New Mexico and Lake Powell in Utah (Archer et al. 1996, Propst and Hobbes 1996, Ryden and Pfeifer 1996a). Red shiner occupies a broad range of habitats, including primary channel shoreline habitats, low-velocity areas associated with the primary channel (e.g., backwaters and embayments), and the array of habitats found in secondary channels (e.g., pools, low-velocity runs, and riffles).

Red shiner is a deep-bodied, laterally compressed minnow with small eyes, a terminal, oblique mouth, and a blunt, rounded snout. This species is well adapted to survive in highly turbid streams with extreme flow variability. Red shiner is highly tolerant to changes in dissolved oxygen, pH, and salinity (Matthews and Hill 1977). Temperature, water velocity, and depth most influenced habitat selection by red shiner in Oklahoma (Matthews and Hill 1979). Matthews and Hill (1980) reported that the species avoided temperature extremes in winter and summer, preferring backwaters or slow-moving deeper water (1 ft) where temperatures were most stable. Throughout the 682 mi north-south span of the red shiners' native range, Matthews (1986) found no significant differences or clinal variation in critical thermal maximum between or among populations. However, it was noted that red shiner was probably the cyprinid most tolerant to high water temperatures. Red shiner was collected in New Mexico from a very warm spring (39.5°C) (Brues 1928).

Reproduction of red shiner was extensively studied (Minckley 1959, Saksena 1962, Taber 1969, Pflieger 1975, Farringer et al. 1979, Gale 1986). Most commonly, spawning occurred from April to October, usually peaking during June and July. Gale (1986) observed fractional spawning over a 2-month period (June to July), wherein several clutches of eggs were produced by a single female. Farringer et al. (1979) suggested the incidence of at least two discrete spawning periods in Oklahoma and Texas. Red shiner nests were found in riffles, sunfish nests, submerged roots, and crevices. Substrates varied from gravel to silt. Males defended a territory where they aggressively chased females. After a usually lengthy courtship (several hours), a male and female passed 1.5 to 2.0 in. over a "nest" where the female and male expelled gametes simultaneously. The fertilized eggs fell into the nest substrata. Gale (1986) described the eggs as yellowish and adhesive with a maximum diameter of less than 0.05 in. Clutch size averaged 585 eggs (Gale 1986). Gale (1986) observed up to 19 clutches from one female. After fertilization the eggs were abandoned and hatched in about 105 hours. Snyder (1981) and Fuiman et al. (1983) described morphology of red shiner larvae.

Farringer et al. (1979) examined scale annuli and suggested that some red shiner may live through two winters and that sexual maturity is reached at age-1 or near 30 mm SL. Laser and Calander (1971) suggested that most red shiner in a population are age-0 and age-1, and that only a few fish reach age-2.

Red shiner is omnivorous and feeds on smaller fishes, insects, algae, crustaceans, and a variety of microorganisms and plant material (Hale 1963, Greger and Deacon 1988, Ruppert et al. 1993).

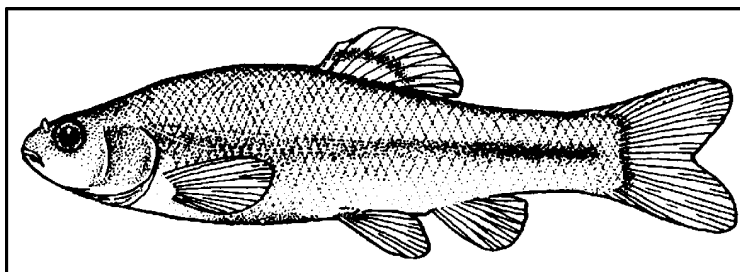
The red shiner is a habitat generalist, capable of numerically dominating fish assemblages in western Great Plains streams (Matthews and Hill 1977). Red shiner demonstrates a high adaptability to environments with greatly fluctuating physiochemical factors (Matthews and Hill 1979). In the Colorado River Drainage, which has been highly modified by anthropogenic activities, red shiner has become well established in several river systems, often becoming the numerically dominant species (Ruppert et al. 1993, Gido et al. 1997, Propst and Hobbes 1997).

The decline of many native western fishes has been attributed, at least in part, to red shiner (Minckley and Deacon 1968). Although the particular mode by which red shiner displaces or negatively interacts with native fishes is uncertain and appears to vary among native species (and life stages of each) and geographic location, predation (Ruppert et al. 1993; Brandenburg and Gido, in press), resource competition (Douglas et al. 1994), and greater fecundity (including extended reproductive season) (Gale 1986) have been suggested. Data to support each mode have been presented. Regardless of how red shiner impacts native fishes, it has been documented that where red shiner is common, native fishes (at least some species) have declined.

Red shiner was the most abundant nonnative fish species in San Juan River secondary channel habitats (Gido et al. 1997; Propst and Hobbes 1997; Gido and Propst, in press). In these studies, red shiner often comprised 50% of the total number of fishes collected, whereas native fishes usually comprised less than 20%. Although spring runoff typically reduced red shiner abundance, red shiner density usually attained pre-runoff levels after the reproductive season.

### **Fathead Minnow**

Fathead minnow is native to the central and upper Mississippi-Missouri-Ohio River Drainage (Lee and Shute 1980). It has been broadly distributed outside its native range, particularly west of the Rocky Mountains, as a bait and forage fish (Carlander 1969, Minckley 1973, Woodling 1985, Sublette et al.



**Plate 3.8. Fathead minnow (*Pimephales promelas*).**

1990). Its hardiness and tolerance of a variety of environmental conditions are one reason it is a popular bait fish and contribute to its widespread establishment outside its native range (Carlander 1969). Fathead minnow was probably first introduced to the San Juan River Drainage in the 1950s or 1960s (Sublette et al. 1990). It is now common throughout the warmwater reaches of the San Juan River (Archer et al. 1996, Propst and Hobbes 1996, Ryden and Pfeifer 1996a).

Fathead minnow is a stout-bodied minnow with a small head and eyes, a small, oblique, terminal mouth, and a blunt, rounded snout. Coloration is typified by an olivaceous back with predorsal dusky stripe behind the head. The sides fade to tan or brown, sometimes with a dusky lateral band. Pflieger (1975) described breeding males as "... mostly black with a broad, yellowish bar encircling

body behind head and a similar bar beneath dorsal fin; large tubercles developed on chin and in 3 rows on snout; forward part of back with a fleshy pad.”

Fathead minnow has been collected in rivers, streams, lakes, and ponds, preferring low-velocity habitats (Becker 1983, Robison and Buchanan 1988). The species is highly tolerant of low oxygen, high temperatures, and turbidity. It was reported by Kochsiek and Tubb (1967) that fathead minnow can tolerate high salinity (>8,000 ppm) for up to 48 hours. In streams with intermittent flow, fathead minnow is often the most abundant fish species collected, mostly in isolated, stagnant pools (Pflieger 1975, Cross and Moss 1987, Sublette et al. 1990). More commonly collected in low-velocity habitats, fathead minnow is often associated with submerged or floating algae (Becker 1983, Sublette et al. 1990).

Spawning of fathead minnow has been reported from April through early autumn (Markus 1934, Prather 1957, McCarraher and Thomas 1968, Scott and Crossman 1973, Andrews and Flickinger 1974, Becker 1983, Robison and Buchanan 1988), depending on geographic location. It has been hypothesized that water temperature, photoperiodicity, or both may influence initiation of spawning by fathead minnow (Andrews and Flickinger 1974). Andrews and Flickinger (1974) hypothesized that day length may be more important in initiating spawning and that water temperature becomes most important as the reproductive season progresses. Spawning begins in the spring or when the water temperature is approximately 15.6E C and continues through the summer and autumn until water temperature is again below 15.6E C (Prather 1957, McCarraher and Thomas 1968). Male fathead minnow select a nesting site, usually under an object, digging out a cavity if necessary (Andrews and Flickinger 1974). One male will spawn with several females while defending a nest from all other males. McMillan (1972) reported “snout-butting” between male combatants. After a complex courtship best described by Burrage (1961), a male maneuvers a female into the nest, then stimulates her to expel eggs while the male simultaneously releases sperm. The male will tend the nest until the eggs hatch (Markus 1934, Pflieger 1975). Fathead minnow females were observed depositing eggs on the undersides of rocks, timber, concrete, tile, and even metal (Markus 1934, Benoit and Carlson 1977). Gale and Buynak (1982) determined that fathead minnow is a fractional spawner. Five pairs of fathead minnow produced 16 to 26 egg clutches with 9 to 1,136 eggs per clutch (Gale and Buynak 1982). One female produced more than 10,000 eggs during a reproductive season. Gale and Buynak (1982) reported no post-spawning mortality. However, Markus (1934), among others, reported post-spawning mortality of both sexes. Mature eggs are orange, demersal, and buoyant, with a maximum egg diameter of less than 0.05 in. (Becker 1983). A secretion by the male adheres the eggs to the underside of the nest cavity (Cross 1967, Smith and Murphy 1974). Eggs hatch in 4.5 to 6 days (Hasler et al. 1946), and larvae remain near the nest until yolk-sac absorption (Becker 1983). Larval morphology and development has been extensively documented (Fish 1932, Markus 1934, Andrews 1970, Snyder et al. 1977, Snyder 1981, Heufelder and Fuiman 1982, Fuiman et al. 1983).

Growth was rapid in some populations with individuals reaching adult size during the first summer (age-0) if an abundant food source is available. However, in most instances, maturity was not

reached until the second summer (age-1) or even the third year (age-2) (Becker 1983). Age-3 fish were rare (Carlson 1967, Held and Peterka 1974, Chadwick 1976).

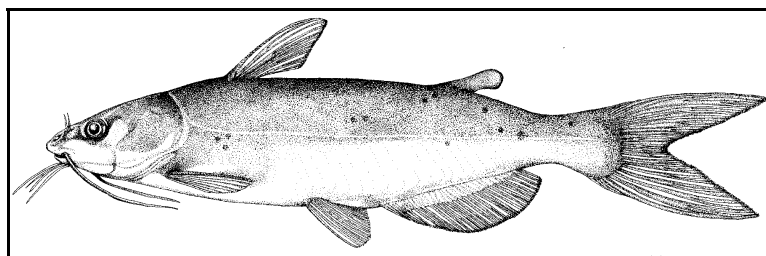
Fathead minnow was observed to feed primarily in soft-bottomed substrates. The majority (80 to 95%) of their diet consisted of algae and other plant material with the remainder comprised of microscopic organisms and smaller aquatic insects (Coyle 1930, Starrett 1950).

Fathead minnow was one of the most important commercially propagated fish species in the United States (Becker 1983, Robison and Buchanan 1988). Miller (1952) reported use of fathead minnow as a bait fish in the lower Colorado River system by the early 1950s. Fathead minnow is commonly found in bait shops in and around the San Juan River Basin. An easily propagated, widely produced species, it may be surmised that control or enforcement to prevent inadvertent introductions into nonnative waters is almost impossible.

The impact of fathead minnow on native fish populations in the San Juan River is unknown. Fathead minnow commonly occupy habitats used by some life stages of several native fish species. Archer et al. (1996) found fathead minnow common in backwater habitats associated with the San Juan River. In secondary channel habitats, Gido and Propst (in press) reported that all life stages of fathead minnow (larvae, juvenile, and adult) occupied the same mesohabitats as native fishes (primarily flannelmouth sucker and bluehead sucker), but that there was temporal segregation in the use of these mesohabitats. Although they did not find direct evidence of competition, it may nevertheless occur.

### **Channel Catfish**

Channel catfish is native to the central United States, south central Canada, and portions of the Atlantic coast and Mexico (Sublette et al. 1990). It is the most widely cultivated warmwater species in North America (Sublette et al. 1990). It is not known when



**Plate 3.9. Channel catfish (*Ictalurus punctatus*).**

channel catfish was first introduced into the San Juan River, but this species was stocked in the Colorado River Basin as early as 1892 (Allen and Roden 1978 as cited by Tyus and Nikirk 1990). It is found in a wide range of warm to cool water habitats and in large rivers, ponds, and reservoirs. In the Yampa River, channel catfish occupy the same habitats as the endangered fishes at all times of the year (Irving and Karp 1995). Channel catfish is omnivorous, consuming a variety of food items including insects, fishes, and plant material (Koster 1957). Spawning occurs during late spring and early summer (Sigler and Sigler 1987, Sublette et al. 1990). Channel catfish reportedly can live almost 40 years (Moyle 1976), though most probably live no more than 10 to 12 years (Sigler and Sigler 1987). Tyus and Nikirk (1990) reported a maximum life span of 22 years in the Green and Yampa rivers.

Spawning occurs during late spring and early summer when water temperatures are about 21 to 29°C (Sublette et al. 1990). In the San Juan River, channel catfish spawn during late June through early August, typically on the descending limb of the hydrograph. In the Green and Colorado rivers, spawning overlaps with Colorado pikeminnow (T. Chart, UDWR, personal communication). Males can spawn several times in a year, while females spawn only once (Lentsch et al. 1996). Based upon radiotelemetry data, there did not appear to be any seasonal pattern of movement associated with spawning in the San Juan River. Spawning nests are built (and guarded) by males in holes, undercut banks, or other protected areas such as rubble or boulders (Sigler and Sigler 1987, Sublette et al. 1990). The eggs are demersal, adhere into a compact gelatinous mass, and are about 3.5 mm in diameter (Sublette et al. 1990, Lentsch et al. 1996). Incubation time is 6 to 10 days at 15.5 to 27.8°C, and larvae hatch at 6 to 9 mm TL (Lentsch et al. 1996). Young channel catfish remain in the nest for 2 to 5 days until the yolk-sac is absorbed (Sigler and Sigler 1987). Males defend both eggs and young for varying periods of time after hatching (Koster 1957, Sigler and Sigler 1987). Age at first spawn varies from 18 months to 8 years (Carlander 1969, Sigler and Sigler 1987), though most probably mature at age-3 to age-5 years (Sigler and Sigler 1987). In the San Juan River, channel catfish probably first spawn at age-4 when they are typically 300 to 325 mm TL.

After emerging from the nest, young channel catfish school for up to several weeks, then disperse (Sublette et al. 1990, Lentsch et al. 1996). Larval catfish have been collected during August (Buntjer et al. 1994) in drift collections indicating that spawning can occur during post-runoff. Though larval channel catfish may “drift” in the San Juan River, it appears their abundance in drift collections is often related to downstream displacement from storm events (Buntjer et al. 1994, Platania 1996). In the Illinois River, Arkansas, Armstrong and Brown (1983) hypothesized that drift of larval channel catfish was related to diel periodicity of feeding.

Young-of-the-year and age-1 channel catfish were commonly found in areas of low velocity, including backwaters (Holden and Stalnaker 1975a, Conklin et al. 1995). In the San Juan River, they were abundant in backwater and flow-through habitats in the middle reaches of the river between Aneth and Mexican Hat, Utah (Buntjer et al. 1993, 1994). There were no documented collections of YOY and age-1 channel catfish in the mainstem of the San Juan River upstream of the San Juan Generating Station (RM 166.1) near Waterflow, New Mexico. The appearance of YOY channel catfish in low-velocity habitat collections varied by year between late July and August (Buntjer et al. 1993, 1994; Archer et al. 1996), indicating variable spawning times. Channel catfish increased in abundance throughout the summer in backwater and flow-through habitats and were usually most abundant in autumn (Buntjer et al. 1993, 1994). Summer and fall habitat requirements were similar to those reported for spring and vary temporally depending upon the annual spawning period.

In the San Juan River, juvenile channel catfish abundance typically increased with increasing distance downstream, with the highest catch rates occurring between Aneth and Mexican Hat, Utah (Buntjer and Brooks 1996). Juveniles (< 300 mm TL) in the San Juan River were commonly collected over sand/silt substrates along cobble bars and in slow run habitats associated with riffles (Brooks et al. 1994). Conklin et al. (1995) indicated that juvenile catfish (< 300 mm) in the Platte River, Nebraska, preferred both low-velocity backwater areas and faster main channel runs. Sigler



and Sigler (1987) reported that young catfish remained in riffles in association with obstacles as barriers to high water velocities. Channel catfish YOY typically occurred year round in low-velocity shoreline habitats in the San Juan River, including backwater and flow-through habitats (Buntjer et al. 1993, 1994; Archer et al. 1996). Their abundance in these habitats in the winter was typically lower than in late summer and fall collections. Conklin et al. (1995) found similar habitat use by young channel catfish year round but did not discuss seasonal differences in abundance.

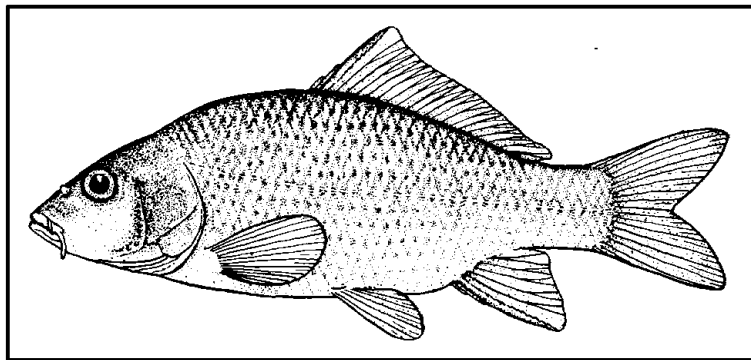
Catch rates for adult channel catfish generally increased with increasing distance upstream between Clay Hills Crossing (RM 3.0) and the San Juan Generating Station (RM 166.1) (Buntjer and Brooks 1996). In the San Juan River, adults were collected in all habitat types, often in association with flannelmouth sucker and bluehead sucker (Brooks et al. 1994). Spring radiotelemetry data showed channel catfish most frequently used run habitat in association with lower-velocity areas including slackwaters, eddies, run/riffles, sand shoals, and sand shoal/runs. As flows peaked during June 1997, two individuals that predominately used main channel habitats throughout the year moved into previously dry channels, presumably seeking refuge from high water velocities or perhaps food. In addition, there were positive electivity values for both eddies and slackwaters, further suggesting that adult channel catfish were seeking refuge from high flows during spring runoff. In the Yampa River, adult channel catfish occupied the same habitats as Colorado pikeminnow at all times of the year (Irving and Karp 1995).

Summer radiotelemetry data indicated habitat use patterns that were similar to those observed during spring in the San Juan River. Adult channel catfish most frequently used run habitat in association with low-velocity areas including slackwaters, eddies, and riffles. One fish occupied flooded vegetation during peak flows in June 1997. Fall habitat use was similar to summer use with respect to frequency of use of run habitat and associated habitat complexity. Adult channel catfish most frequently used run habitat in association with eddies, riffles, run/riffles, and cobble shoals. The distribution and abundance of juvenile and adult channel catfish were correlated with cobble-type habitats during fall base-flow conditions. On average, adult channel catfish occupied less complex habitats in summer and fall than in spring. Though no juvenile channel catfish were implanted with radio transmitters in the San Juan River, a study done in the Platte River, Nebraska, indicated similar habitat use by season for juvenile channel catfish (Conklin et al. 1995). Conklin et al. (1995) found juvenile channel catfish preferred low-velocity backwater areas and faster main channel runs, and were most frequently associated with sand and a combination of sand and silt substrates. In addition, they were generally found in areas associated with the river banks, particularly near exposed roots and brush piles.

Winter radiotelemetry data revealed that adult channel catfish most frequently occupied run habitat in association with eddies, slackwaters, and run/riffles, similar to both fall and summer habitat use. The average habitat complexity of areas occupied by channel catfish in the winter was also similar to both summer and fall. However, unlike summer and fall, and similar to spring runoff, during winter adult channel catfish were seeking areas of lower velocity.

## **Common Carp**

Common carp is native to Europe and Asia, and was first introduced in the United States in 1831 (Sublette et al. 1990). The introduction of common carp in the San Juan River likely occurred in the early to mid-1880s (Holden and Stalnaker 1975a, Sublette et al. 1990). Common carp are capable of adapting to a wide variety of environmental conditions (Minckley 1973, Lentsch et al.



**Plate 3.10. Common carp (*Cyprinus carpio*).**

1996), but seek warm, shallow, vegetated, low-velocity habitats (Sublette et al. 1990). In the Upper Basin, they are abundant in sheltered habitats, including backwaters, shorelines, and along tamarisk-lined banks (Valdez 1990). Common carp is truly omnivorous, consuming aquatic invertebrates, algae, organic debris, plants, and occasionally fish eggs (Cooper 1987, Sublette et al. 1990). Spawning occurs from April to late August (Carlander 1969, Sigler and Sigler 1987). Common carp can live 47 years in captivity (Carlander 1969) though the average life expectancy is 9 to 15 years (Sublette et al. 1990, Lentsch et al. 1996).

Spawning occurs in a wide variety of habitats in water temperatures of 10 to 30E C (Lentsch et al. 1996) with 17 to 23E C generally considered optimum (Carlander 1969, Sublette et al. 1990). In the San Juan River, carp likely spawn from late-April through August, peaking some time in June or July. In the Yampa River, carp spawn from mid-May through mid-August with peak spawning between early-June and early-July (Lentsch et al. 1996). Spawning usually involves one female and a group of males (Minckley 1973). Females may spawn twice in a season, releasing most of their eggs in the first spawn (Carlander 1969). The slightly adhesive eggs (0.9 to 2 mm in diameter) are broadcast at random in shallow water along the shore, often over submerged vegetation, debris, or rubble (Koster 1957, Carlander 1969, Minckley 1973). Age at first spawn is 1 to 4 years for males and 2 to 5 years for females (Carlander 1969). In the San Juan River, few juvenile carp have been collected, making it difficult to follow cohorts through time and estimate age at first spawn. However, because trends in annual adult carp collections generally track adult channel catfish collections (Buntjer and Brooks 1996), it is possible to assume carp in the San Juan River are mature (>250 mm TL) by age-2 or age-3. Ripe males have been observed that were 250 to 350 mm TL.

Egg incubation time was 3 to 5 days at 20E C and 5 days at 15E C (Lentsch et al. 1996), but could be up to 16 days depending upon water temperature (Sublette et al. 1990). Larvae hatched at 4 to 5 mm TL (Lentsch et al. 1996) and remained attached to vegetation until they completely absorbed their yolk sacs, generally within 5 days (Cooper 1987). Though larval carp were reported as being common in drift collections in some rivers (Gale and Mohr 1978), their collection in the San Juan River drift was primarily incidental (Buntjer et al. 1994, Platania 1996).

After hatching, common carp remained near shore for a period of time, then dispersed to sheltered areas as juveniles (Minckley 1973). Young-of-the-year and age-1 carp were commonly seined in backwater and flow-through habitats in the San Juan River, though seldom in large numbers (Buntjer et al. 1993, 1994; Archer et al. 1996). Holden and Stalnaker (1975a) reported similar findings for carp in backwater habitats of the Upper Basin. Catch rates for YOY and age-1 carp in secondary channels from 1991 to 1996 were considerably higher than those reported for main channel habitats, particularly in 1993 and 1994 (Buntjer et al. 1993, 1994; Archer et al. 1996). Propst and Hobbes (1995, 1996) found common carp were most abundant in upstream reaches (above RM 115) and were the most abundant nonnative in spring secondary channel electrofishing collections. Thus, secondary channel habitats in the San Juan River appeared to be seasonally important nursery areas for YOY and age-1 carp, particularly in upstream reaches. Young carp abundance in low-velocity shoreline habitats in the winter was typically lower than in late summer and fall collections (Buntjer et al. 1993, 1994; Archer et al. 1995, 1996).

Few juvenile (<250 mm TL) carp were collected in the San Juan River (Buntjer and Brooks 1996), making it difficult to describe their distribution, abundance, or habitat requirements. In addition, there were few, if any, riverine studies in the Upper Basin that discussed juvenile carp. Conklin et al. (1995) described habitat selection for common carp in the Platte River, Nebraska, but the majority (96%) of carp collected were greater than 300 mm TL. In general, it is believed that juvenile carp seek warm, protected areas.

Catch rates for adult common carp generally increased with increasing distance upstream between Clay Hills Crossing (RM 3.0) and the San Juan Generating Station (RM 166.1) (Buntjer and Brooks 1996). During the spring in the San Juan River, adult carp were most abundant in deep, low-velocity eddies along the shore over sand and silt substrate (Brooks et al. 1994). During the summer, adult common carp were most abundant in shoreline habitats over sand and silt substrate in slow- to moderate-run habitats (Brooks et al. 1994). There is no information regarding winter habitat use in the San Juan River. However, other studies have shown that common carp move in response to water temperature and move to deeper areas in winter where water temperatures are warmer (Koster 1957, Otis and Weber 1982). Small adult carp (350 to 450 mm TL) commonly occupy open, shallow areas downstream of riffles and adjacent to run/pool complexes (Brooks et al. 1994). They were also frequently abundant in slow- to moderate-velocity run habitats. Conklin et al. (1995) observed similar habitat use (and selection) by adult carp in the Platte River, Nebraska. In the Yampa River, adult carp occupied the same habitats as the endangered fishes at all times of the year (Irving and Karp 1995).

Common carp are potential predators on the eggs and young of native fishes in the San Juan River, and they may also be potential competitors with young native fishes. Although common carp are common in much of the Colorado River Basin, only in Lake Mohave have they been observed actually eating eggs of a native fish species (razorback sucker) (Minckley et al. 1991).